LUND UNIVERSITY
School of Economics and Management

Master's Program in Innovation and Spatial Dynamics

Economic development and national environmental performance

A cross-country comparison

by

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Abstract. The relationship between economic development and environmental performance has gained much attention since the development of the environmental Kuznets curve, which predicted that economic growth would lead to environmental degradation at early stages of development but would eventually improve environmental quality at higher income levels. This assumption of economic growth alone driving both causing and solving environmental issues is a potentially risky idea, and thus, scholars are examining the other potential factors behind the relationship. This study contributed to the field by examining the factors affecting the environmental performance index (EPI), a measure which better captures the complexity of environmental quality. The study uses a cross-sectional sample of 148 countries to further examine the factors behind the economic development–environmental performance relationship at different levels of income. Ordinary least-squares (OLS) regression results show that economic development, measured as human development index (HDI), has a positive effect on EPI, and furthermore support the roles of the structure of the economy and government. The study cannot, however, support the idea of international trade either causing environmental degradation or improving the broader environmental quality.

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1 Introduction

The environmental issues have demanded increasingly more attention from governments, international organizations and scholars throughout the end of the twentieth century and early twenty-first century (Fiorino, 2011). For economists, the major concern has been the role of economic growth in environmental degradation. The massive growth of economic activity has resulted in environmental damage and increased emissions that now threatens the public health and the broader ecosystem (EPI, 2018). Stern (2008) described greenhouse gases as "the biggest market failure the world has seen". As global warming becomes an even greater issue, governments and scholars in multiple fields are increasingly seeking emission-reducing policies and technologies. The target is to keep the global temperature increase below two degrees centigrade, which is enforced by the recent Paris Agreement, currently ratified by 174 countries (UN, 2018c). This target will demand both developing and developed countries to take the necessary actions to reduce their emissions to a sustainable level. In addition to reducing carbon emissions, the United Nation (UN, 2018b) lists several environmental goals as a part of their broader sustainable development goals, including clean water and sanitation, affordable and clean energy responsible consumption and production, and sustainable life on both under the water and on land.

The latest environmental performance index (EPI, 2018) scores and ranks countries based on their performance on the UN's sustainability goals and the Paris Agreement. The report includes 180 countries, whose scores have constructed from 24 individual indicators divided into environmental health and ecosystem vitality. This index offers a metric that challenges the more commonly used measures of pollution concentrations and energy usage by capturing the more complex nature of environmental performance. The latest results suggest, that economic development has a key role in environmental performance (Figure 1; Figure A). High-income countries generally perform better than countries at lower income levels. This leads a question of whether economic growth could in fact improve environmental performance.

The question is not new. Several economists, such as Panayotou (1993), Grossman and Krueger (1991, 1995), Selden and Song (1994) and Dasgupta et al. (2001) have examined the decoupling of economic growth and environmental damage at higher income levels. The phenomenon is known as the environmental Kuznets curve (EKC), which was based on Kuznets (1955) hypothesis of the relationship between economic growth and income inequality forming an inverted U-shaped curve. The inequality would increase together with income until a turning point, after which further economic growth would decrease the inequality. The idea was connected to the environmental performance in early 1990s (Grossman & Krueger, 1991; Shafik & Bandyopadhyay 1992; Panayotou, 1993). This challenged the earlier beliefs of economic growth increasing emissions monotonically through increased economic activity and outputs, causing inevitably more emissions as a by-product (Torras & Boyce, 1998; Fiorino, 2011).

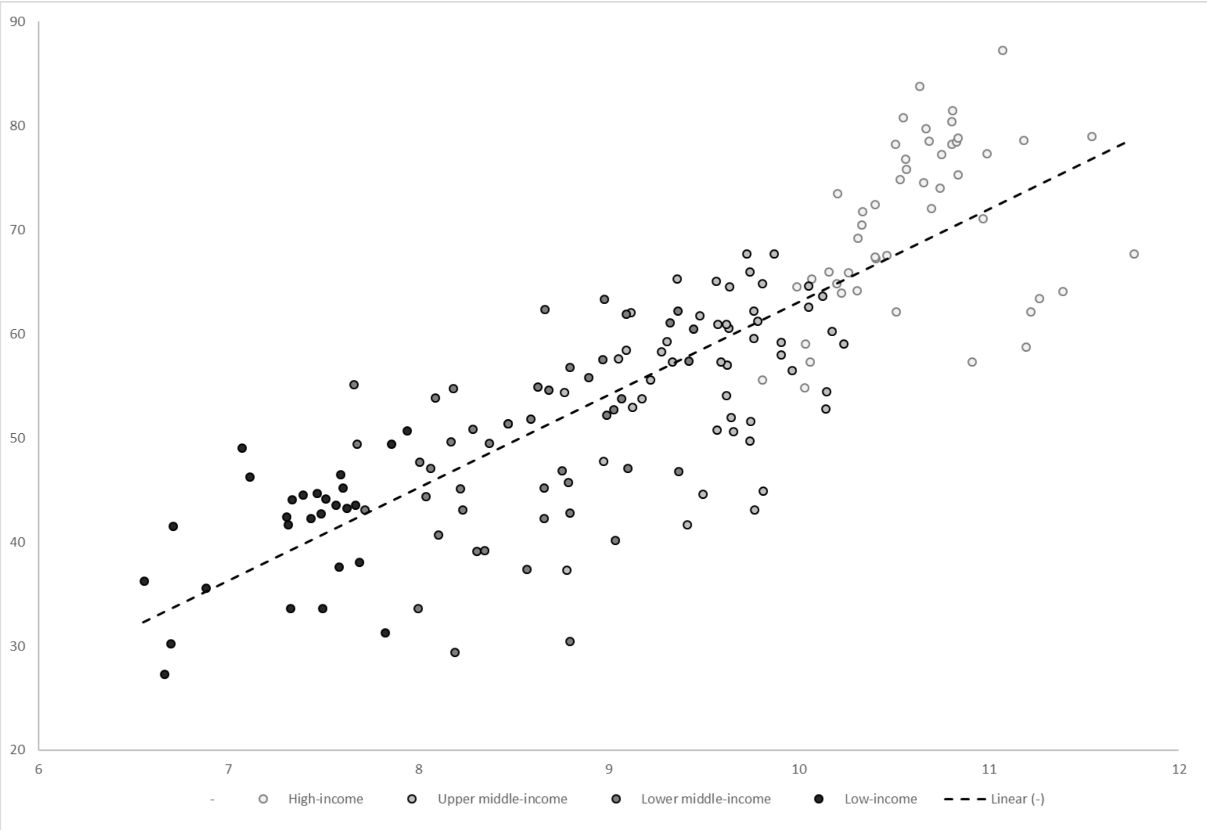

Figure 1. Log GDP (purchasing power parity corrected) per capita (x-axis) and EPI 2018 score (y-axis) among 170 countries (World Bank, 2018a: EPI, 2018)

A closer look at the relationship reveals, that not all differences between countries' environmental performance can be explained by different incomes. While the majority of economists agree that economic growth by itself is not the cause of improved environmental performance, the exact mechanism of the relationship remains unclear (Stern, 2004; Dinda, 2004; Tsurumi & Managi, 2010). Several factors have been suggested to explain the relationship. Structural change from mainly agrarian to manufacturing economies has been connected to increased emissions, and shift from manufacturing to service economies to decreasing emissions (Panayotou, 1993; Torras & Boyce, 1998). Other factors include adoption of cleaner technologies (Grossman & Krueger, 1995), replacing domestic production with improts (Copeland & Taylor, 2004), and stricter environmental regulations and policies (Panayotou, 1993; Dinda, 2004; Bagayey & Lochard, 2016). The results so far have been mixed. While economic growth and development have been connected to the decline of some pollutants, it has failed to improve other areas of environmental quality. The majority of studies up to date have focused on a few pollutants and energy use, omitting other environmental damages.

In this thesis, the focus is on the factors driving the national environmental performance both between different income levels and countries at similar income levels. The key contributions are the use of broader measure of environmental performance, namely the EPI, and a broader measure for economic development, the human development index (HDI), to address the critique toward the gross domestic product (GDP) as a measure of standard of living and well-being. The strength of the results lies in the wide set of countries included. The latest EPI score is available for 180 countries, and the sample used here includes 148 countries spanning all income levels and continents, excluding Antarctica. This study uses the World Bank (2017) classification of countries based on their gross national income (GNI). However, the GDP measures used in Figure 1 are purchasing power parity (ppp) corrected international dollars, which causes some overlapping between income levels. Using current dollars for income measures will overestimate the incomes at higher levels and underestimate at lower levels (Stern, 1998).

1.1 Research Problem and aim of the study

Earlier studies have been ambiguous about the exact measure of environmental performance. The most common measures include concentrations of sulphur dioxide (SO_2), carbon dioxide (CO_2), nitrogen oxides (NO_x), particulate matter (PM), and energy use (Tsurumi & Managi, 2010; Fiorino, 2011). Some studies have included water pollutants, such as fecal coliform, biological and chemical oxygen demands, and metals (Fiorino, 2011). However, the measures are often treated individually. Studies have found decoupling with economic development for some pollutants, but even then, there are no commonly agreed turning point, where the emissions start decrease with increasing income (Halkos, 2003, Stern, 2004). Stern (2004) has further criticized the idea of EKC being "econometrically weak" and that there is not enough attention paid "to the statistical properties of the data used". In this study, the weakness of the earlier measures for environmental performance was addressed by applying a broader metric for environmental performance, discussed above. Furthermore, more attention is paid to pre-estimation and post-estimation robustness tests, to improve the validity of the results. The results are additionally compared to a more commonly used environmental measure, CO_2 emissions.

The literature has identified and examined several possible drivers (see above) of the economic development–environmental performance relationship. However, the results have been mixed, and different outcomes are found for different pollutants. In this study, the aim is to review the literature and identify the key factors and examine their impact on environmental performance. Furthermore, the aim is to identify those factors that best explain the differences between countries at similar income levels. The results are compared to those of CO_2 concentrations. The aim is to examine, whether the broader environmental performance measure has a different development pattern than that of CO_2 emissions, which are expected to monotonically increase with income (Torras & Boyce, 1998).

The research questions are:

RQ1. *What are the driving factors of environmental performance?*

RQ2. *What explains the differences in environmental performance at similar income levels?*

The two questions are addressed through a literature review of previous studies on the environmental performance and then tested empirically and compared to an alternative measure for environmental performance, namely the CO_2 emissions often used in the EKC literature. Although this study does not attempt to test the existence of EKC, the vast literature on the phenomenon offers a broad source of possible explanations of the decoupling of environmental degradation and economic growth. In the following section, the study will present the theoretical background and arguments of EKC and form hypotheses on the key factors identified from the literature. The data and models are presented in the third and fourth sections. The empirical results are introduced in the fifth section and concluded in the final section.

2 Theory

The relationship between economic growth and environmental performance have been of interest to the scholars due to the increased concern over global warming and environmental degradation (Torras & Boyce, 1998). Keeping the temperatures below the two-degree threshold is now a key international policy objective. While industrialized countries have been cutting down their share of global CO_2 production, industrializing countries, such as the BRIC countries (Brazil, Russia India and China), are increasing their shares of the global production (Tamazian et al. 2009). The relative decline of emissions and energy use at higher developmental stages has caused scholars such as Grossman and Krueger (1991, 1995) and Panayotou (1993) to hypothesize an inverted U-shaped curve describing the relationship between economic growth and environmental degradation. Although heavily criticized for its simplistic implications of developing countries being “too poor to be green” (Perman & Stern, 2003), there has been evidence of such relationship existing. In this section, the literature on the economic growth and environmental performance is reviewed. The aim is to identify the potential drivers of the relationship and evaluate different measures for both environmental and economic performance. At the end of this section, the theoretical assumptions are presented together with testable hypotheses.

2.1 Previous Research

The concept of EKC emerged from pioneering studies by Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992) and Panayotou (1993), which were the first studies that connected the idea of Kuznets curve (Kuznets, 1955) to environmental performance. Up until the emergence of the EKC, economic growth was seen more as a threat to the environment, than a potential solution (Stern, 2004). Despite the heavy criticism that the idea of EKC has received, the EKC literature serves here as a rich source of potential drivers for environmental performance for different levels of income. In this section, the original ideas of upward and downward shifting curves are examined, together with an examination of both theoretical and empirical criticism. Furthermore, two of the factors are considered to a greater detail; the roles of international trade and the quality of governance.

2.1.1 Economic development and environmental performance

The original idea for the EKC began from the studies of Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992) and Panayotou (1993). Grossman and Krueger (1991) found that for SO_2 and smoke, the inverted U-shaped curve-relationship with economic growth exists. Shafik and Bandyopadhyay (1992) found monotonically improving access to clean water and urban sanitation, but a worsening river quality in terms of dissolved oxygen and fecal coliforms, with increasing incomes. Local air pollutants were found to follow a bell-shaped curve, where SO_2 and suspended particulate matter (SPM) initially increase with GDP but decreases again at higher GDP. Panayotou (1993) found an EKC for both deforestations and SO_2 emissions.

The early studies assumed the relationships to be driven by scale, technique and composition effects (Dinda, 2004). The scale effects are those that are directly related to the growing economic activity, such as increased use of motorized vehicles and electricity generation (Grossman & Krueger, 1991). Increasing activity requires more inputs and produces more outputs, which include the negative by-products such as emissions (Dinda, 2004). Thus, countries with lower economic activity would have lower environmental degradation. However, the EKC would indicate, that the increased emissions by increased scale effects are overcome by introducing better, more resource-efficient and cleaner technologies (Grossman & Krueger, 1991). Countries with higher incomes can better afford to develop and adopt cleaner technologies (Dinda, 2004). Finally, the composition effects indicate, that the environmental performance is explained by the structural change the economy goes through during its development (Grossman & Krueger, 1991; Dinda, 2004). Less developed countries tend to be mainly agrarian, with low levels of energy consumption and related emissions. As the economy shifts from agriculture to manufacturing, the energy requirements and emissions are increased. Most developed countries have reached the latter sage of development and shift from manufacturing to service-based economies, with more sophisticated industries and energy-scarce services as main compositions of total output (Panayotou, 1993; Torras & Boyce, 1998; Dinda, 2004). However, as Torras and Boyce (1998) argued, the decrease of the manufacturing sector needs to be absolute as well as relative in order to see decreases in emissions. This would indicate, that either the manufacturing goods are inferior, and thus experiencing a lower demand curve at higher incomes, or that the local production is replaced by imports.

However, these three effects do not fully capture the mechanism of how economic growth impacts the environment. International trade has both effects on economic growth, by allowing countries to trade and increase their incomes (Grossman & Krueger, 1991), and on environment, through relocating pollution to countries with lower regulation, creating so-called "pollution havens" (Copeland & Taylor, 2004; Dinda, 2004). Another factor of the EKC is governance, as the demand for stricter environmental regulations are expected to grow as incomes and standard of living of the citizens increase (Panayotou, 1993; Torras & Boyce, 1998; Dinda, 2004). Both the effects from international trade and governance are discussed further below.

Since the pioneering studies of the EKC, scholars have been testing the hypothesis on other pollutants and environmental degradations. The most commonly studied performance indicators are NO_x, PM, SO_2, CO_2 concentrations and energy use (Tsurumi & Managi, 2010, Fiorino, 2011). Of these three measures, SO_2 has had the most supportive evidence for the EKC. Inverted U-shaped curves have been found by Selden and Song (1994), Grossman and Krueger (1995), Panayotou (1997) and Millimet et al. (2003). The existence of the curve for SO_2 has been explained by the local and immediate consequences of increased emissions (Tsurumi & Managi, 2010). However, Stern and Common (2001) criticized the findings and argued that they do not hold at the global level. Their study found a lower turning point for OECD countries, but the results were sensitive to the exact sample of the countries. Thus, a single global EKC for SO_2 does not exist, but is rather a misspecification of the model. For CO_2, the results have shown either a monotonic increase at any income level (Shafik, 1994, Azomahou et al. 2006) or a turning point outside of the sample at unrealistically high-income levels (Holtz-Eakin & Selden, 1995; Halkos, 2003). This has been explained by the global effects of CO_2 emissions as opposed to more localized effects, such as those of SO_2 emissions (Shafik, 1994). Therefore, incentives to reduce SO_2 emissions are higher, explaining the lower turning point, than for CO_2 (Tsurumi & Managi, 2010). Energy use has demonstrated mixed evidence of EKC behavior. Most of the studies have failed to find a turning point for energy use, or it lies outside of the sample (Tsurumi & Managi, 2010). Tsurumi and Managi (2010) found a large declining slope for SO_2 and slightly declining shared of CO_2 and energy use per capita at higher income levels. Other measures of environmental performance in the EKC literature have included smoke, suspended particulate matter (SPM), heavy particles (Grossman & Krueger, 1995), lack of clean water and urban sanitation, deforestation, and dissolved oxygen and fecal coliforms in rivers (Shafik & Bandyopadhyay, 1992).

The most common methodologies used in the EKC literature are econometric in nature. Perhaps the most used data source is the Global Environment Monitoring System (GEMS), which includes common air and water pollution-related data for over 1000 locations globally (Torras & Boyce, 1998; Dasgupta et al. 2002). Other sources for pollutants include Aerometric Information Retrieval System (AIRS) and the World Health Organization (WHO). For energy, studies have used the International Energy Agency (IEA) for energy use per capita (Suri & Chapman, 1998). A common issue in EKC literature is the scarcity of data. Although data for some pollutants is widely available, there are “literally thousands of potentially toxic materials [that] remain untested and unregulated” (Dasgupta et al. 2002). Data issues are likely to cause problems with econometric models, as the presence of heteroskedasticity will make OLS estimates inefficient (Stern et al. 1996).

The most common measure for economic growth is the GDP per capita, either in ppp-dollars or current USD (Stern, 2004). The standard EKC model includes the quadratic form of the GDP, and some studies have additionally used its cubic form (Suri & Chapman, 1998). However, the use of GDP as a measure of economic development has not been questioned in the EKC literature. Although Dinda (2004) argued, that “[a]s income grows, people achieve a higher standard of living and care more for the quality of environment they live in and demand for better environment induces structural changes in economy that tends to reduce environmental degradation”, there is a question of whether GDP is the best measure for standard of living. The GDP is used to measure a country’s output in monetary terms, and it has been criticized of being biased toward manufacturing and tangible goods (The Economist, 2016).

The general EKC-model used in earlier studies include the environmental factor as the dependent variable and GDP per capita and its quadratic and sometimes cubic form as independent variables. Country and time-specific effects are included, as well as the error term for unobserved effects. Control variables vary among studies, as discussed above. Suri and Chapman (1998) presented the following model, which is also used in earlier studies, such as Grossman and Krueger (1991, 1995), Selden and Song (1994) and Holtz-Eakin and Selden (1995):

$$Y_{it} = a_i + \gamma_t + \beta_1 X_{it} + \beta_2 X_{it}^2 + \beta_3 X_{it}^3 + \beta_k Z_{kit} + \varepsilon_{it} \quad (1)$$

Where Y_{it} is the environmental factors in a country *i* at time *t*, such as a single pollutant or the energy usage, and X_{it} represents the GDP per capita. Control variables are included in the Z_{kit} term. The country-specific effects are captured by a_i and time-specific effects by γ_t. The error term ε_{it} captures all other unobservable effects.

Most of the early studies on EKC have been criticized for their assumptions of a unidirectional effect from growth to environmental performance (Stern et al. 1996) and for the lack of decomposing the possible causes of the income-effect (Stern, 1998). The environmental issues could hinder economic growth, driving the causality from environmental to economic performance as well (Arrow et al. 1995; Stern et al. 1996). In a later paper, Stern (2004) reviewed a large set of EKC literature and expressed further criticism toward the theoretical and empirical basis. According to his review, the idea of economic growth both causing and solving environmental issues lacks wisdom, as rapidly growing countries experience scale effects that overcome the time effect, and slower growing high-income countries experience the opposite. The EKC is sensitive to the econometric specification, and many studies have issues with heteroskedasticity, simultaneity, omitted variable bias and cointegration. The theoretical basis is often weak, giving weak support for reduced-form empirical analysis, and the results are often less robust than claimed (Harbaught et al. 2002, Stern, 2004). Dasgupta et al. (2002) highlight the issue of appropriate functional forms and data scarcity. In addition, Stern (2004) raises concerns about the lack of a commonly agreed upon turning point, where environmental performance starts to improve.

To address some of the critique, studies have conducted cointegration analyses to determine the Granger causality between economic growth and environmental performance. However, the results have been inconclusive and dependent on the geographical context. Condoo and Dinda (2002) suggested, that in developed countries, the causality runs from emissions to income, but opposite in the developing countries in Central and South America, and bidirectional in Asian and African countries. Soytas et al. (2007) examined the environmental performance in the US but found no Granger causality from income to emissions in the long run. However, they found, unsurprisingly, that energy consumption does exhibit Granger causality of emissions, but there is no causality from emissions to energy use. Jalil and Mahmud (2009) conducted a similar study on China’s emissions and found a one-way

Granger causality from economic growth to CO_2 emissions. Apergis and Payne (2009) found Granger causality from energy use to GDP in Central American countries. Acaravci and Ozturk (2010) similarly found a unidirectional causality running from energy use to GDP in seven European countries (Denmark, Germany, Greece, Iceland, Portugal and Switzerland), but this was not confirmed for the other 12 countries included in their sample. Jaunky (2011) tested the EKC hypothesis on a panel of 36 high-income countries by using a panel vector error correction model (VECM). The findings suggested that there is a cointegration between GDP and CO_2 emissions and both short-run and long-run unidirectional Granger causality from GDP to emissions. The EKC was only confirmed for individual countries but not for the whole panel. Thus, the evidence of EKC is mixed, and largely dependent on the econometric specification, data and context.

2.1.2 Trade and environment

The early EKC literature already expressed concerns of free trade causing relocation of pollution-intensive activities (Grossman & Krueger, 1991). International trade is seen as "one of the most important factors that can explain EKC" (Dinda, 2004). Typically, the effects of trade liberalization are connected to scale, technique and composition effects (Cole & Elliot, 2002). These effects refer to the changes in size of the economy, production methods and industrial structure. International trade can cause growth in economic activity, which could potentially increase emissions as a by-product (Dinda, 2004). Another mechanism is the potential transfer of cleaner technologies through foreign direct investment (FDI). For economic structure, trade liberalization may mean more specialized production, thus driving some countries to further focus on their competitive advantage (Cole & Elliot, 2003).

In a pioneering study, Grossman and Krueger (1991) examined, how free trade affects the environment, using the example from the trade agreement between the US and Mexico. At the time, there were concerns of increasing emissions in Mexico because of the North American Free Trade Agreement (NAFTA), as the environmental regulations were weaker than those in the US. However, the authors saw trade as an opportunity for a lesser developed country to increase income, which would in turn put more pressure on the environmental performance. Additionally, they suggested that international trade could enable technological transfer, which would help countries to adopt cleaner technologies. Shafik and Bandyopadhyay (1992) provided empirical support for greater openness to trade resulting in cleaner production technologies. However, their evidence of free trade decreasing pollution was lacking.

International trade is still seen as potentially harmful for the environment (Copeland & Taylor, 2004; Cole, 2004; Kearsley & Riddel, 2010). In particular, there are concerns of stricter environmental regulation driving companies to offshore their manufacturing plants to countries with weaker regulations (Agras & Chapman, 1997; Dasgupta et al. 2002; Copeland & Taylor, 2004). This phenomenon is also known as the "pollution haven hypothesis", displacement hypothesis, or carbon leakage. The evidence of the hypothesis is limited, and the measured effect is often weak, as the pollution abatement costs are seen as a minor part of a company’s overall costs (Levinson & Taylor, 2008). Suri and Chapman (1998) argued that imports from developing countries have played a significant role in flattening the EKC curve for energy use at high-income countries. Antweiler et al. (2001) found a statistically significant but weak positive impact from openness to trade on pollution. Cole (2004) found no consistent pattern of firms relocating their activities based on pollution abatement costs. In cases where supportive evidence was found, the economic significance was limited. Smarzynska and Wei (2004) looked at firm-level data and accounted for corruption in the host country, and found only limited support for the pollution haven hypothesis, which was not robust to sensitivity checks. Frankel and Rose (2005) found openness to trade to reduce some emissions, rather than increase. Over all, they did not find support for the pollution haven hypothesis. Kearsley and Riddel (2010) further found no correlation between trade openness and increased emissions in developing countries. They argue that there is not enough evidence to support the hypothesis.

More recent studies, however, have found more evidence of carbon leakage. Aichele and Felbermayr (2012, 2015) estimated, that countries committed to the Kyoto agreement imported 8 percent more carbon than countries which were not committed. Furthermore, they argue that the Kyoto Protocol has indeed increased the occurrence of carbon leakage. In addition, Martínez-Zarzoso et al. (2017) found evidence of increased emissions in exports to advanced countries resulting from stricter environmental regulation. Supportive evidence was provided by Bagayey and Lockhard (2016) who examined the EU environmental regulation, and found that stricter regulation was connected to rising polluting activity in emerging countries due to growth in exports to developed countries. Based on the evidence, it appears that while openness to trade in itself has not been successfully connected to the pollution haven hypothesis, increased environmental regulation may be a more direct cause.

Another factor related to trade and environment is the effect of foreign direct investment (FDI) on environmental performance. If the strict environmental protection causes companies to relocate their activities, one would see a positive relationship between received FDI and emissions. However, studies have found inconclusive evidence. Dasgupta et al. (2002) examined the FDI inflows to China, Mexico and Brazil and their urban pollution, and found a negative impact from FDI on pollution. In their study of developing countries, Neequaye and Oladi (2015) found, that FDI has a statistically significant, negative impact on emissions. Zakarya et al. (2015) found a unidirectional Granger causality from FDI to CO_2 emissions in BRIC countries. Omri et al. (2015) studied a panel of 54 countries and found suggestive evidence that the Granger causality runs both ways. The Abdouli and Hammami (2015) study examined FDI flows and CO_2 emissions in Middle-Eastern and North-African countries. They found a significant positive impact of FDI on CO_2 emissions, which could support the pollution haven hypothesis. However, their study additionally suggests that CO_2 emissions have a positive impact on FDI, making a bidirectional causality possible. Bakirtas and Cetin (2017) do find evidence of a positive effect of FDI on CO_2 levels by using a panel cointegration model for Mexico, Indonesia, South Korea, Turkey and Australia.

2.1.3 Governance and environment

Policies and regulations are likely to drive environmental performance and be connected to the relationship between economic growth and environment (Dinda, 2004). The studies of Grossman and Krueger (1991) and Panayotou (1993) suggested that governments do play a significant role in reducing emissions and other environmental damage at higher income levels, where increased standard of living drives up the demand for environmental quality. Esty and Porter (2005) called for a better systematic statistical analysis of the role of policies and regulation on environmental performance. However, the lack of an internationally comparable measure for environmental regulations has provided limitations for more sophisticated analysis (Sauter, 2014). Indicators have included survey-based measures, monetary indicators, such as pollution abatement costs, policy specific measures and performance indicators. Brunel and Levinson (2016) reviewed the most common measures and concluded that most fail to meet the criteria for a good, internationally comparable measure. The complexity and uniqueness of countries' environmental policies makes it extremely challenging to capture environmental stringency with a single quantified measure.

Most of the studies addressing political aspects of environmental performance thus rely on addressing the wider political economy and government. Torras and Boyce (1998) used literacy rates, income inequality and political rights to measure political inequality of a country. Although power inequality is generally negatively associated with environmental performance, political rights and literacy has a particularly strong effect on emissions at lower income levels. Dasgupta et al. (2001) surveyed UN reports including 31 countries to examine the level of environmental regulation and performance and found a strong positive connection with economic development. Frankel and Rose (2005) found a positive relationship between democracy index and environmental quality. Barrett and Gaddy (2000) examined the role of political and civil freedoms in the relationship between income and environmental performance. However, they did not find significant relationship with all of their environmental measures. Esty and Porter (2005) examined the environmental regulatory regime and economic and legal context and found that countries with stricter environmental regulations performed economically just as well, if not better, than those with weaker environmental regulations. Pellegrini and Gerlagh (2006) used the same environmental regulatory regime developed by Esty and Porter (2005) to examine how the level of democracy affects the environmental policies. However, their study does not find evidence of relationship between democracy and environmental regulation. Apostoaie and Maxim (2017) studied the political determinants for environmental performance at the European Union (EU). By using measures for political corruption, level of democracy, government effectiveness, and government quality, they found that effective governments have a better ability to implement environmental policies and thus, improve environmental performance.

One of the dangers of implementing stricter environmental policies is the productivity losses it may cause (Ambec & Barla, 2006). This idea was, however, challenged by Porter and van der Linde (1995) by proposing that environmental regulation provides firms external pressure to "overcome organizational inertia" and produce new less-polluting technologies (Ambec &

Barla, 2002). In this way, environmental regulation can stimulate economy. However, the type of regulation is important. The study by Mohr (2002) shows, that it is possible to pose an environmental regulation that both reduces emissions and increases productivity if the policy successfully drives new innovations on abatement technologies. The industry might, however, oppose the new regulations, indicating that they do not see the benefits from it, either because the costs are higher than the assumed benefits, or, as Porter has argued, the industry fails to comprehend the benefits in the long run (Mohr, 2002). Greaker (2006) further supports the possibility of improving productivity while reducing emissions, but that there is more to the industry resistance. He argues that the total costs might increase even when marginal costs are decreasing, which might increase the industry resistance for environmental regulation. Additionally, a firm's point of reference is often zero environmental policy, and therefore marginal production cost is always higher with regulation than without.

2.2 Theoretical Approach

Environmental performance has been linked to economic growth, but studies disagree on whether economic growth as such can improve the environmental performance. The empirical evidence of economic growth first causing increased emissions at lower levels of development and then decreasing emissions at higher levels, has been largely criticized (Stern, 2004). The measure of environmental performance used in this study, the EPI score, forms a more linear relationship, showing a constant improvement of environmental quality over a cross-section of 170 countries (see Figure 1 and Figure A), and therefore it is unlikely, that there is an EKC curve to be found. Additionally, as a greater EPI score indicates better performance, the hypothesized curve, where middle-income countries would show decreased environmental performance, would be a U-shaped curve, rather than bell-shaped. In a case of a global EKC curve, a cross-section of countries would show low-income countries at the left-hand side and high-income countries at the right-hand side, both with high levels of environmental performance. Middle-income countries would represent the lower environmental performances between them, forming the U-shaped curve. However, as argued by Stern and Common (2001), the existence of one global EKC is likely a misspecification. Furthermore, in the case where the EKC exists, it is likely to be more of a dynamic model of a long-term phenomenon (Dinda, 2004), than a global cross-section.

Although evidence suggests that certain emissions, such as CO_2, are monotonically increasing with increasing income (Shafik 1994), other environmental factors, such as SO_2, have shown a decreasing pattern at higher income levels (Selden & Song, 1994; Grossman & Krueger, 1995). The EPI score measures several indicators for environmental quality, emphasizing both the environmental related public health issues and the state and sustainability of the ecosystem. Therefore, it is more likely to have a monotonically positive relationship with development, given that citizens of high-income countries can better afford the cost of abatement (Dinda, 2004) and the high-income countries themselves have the possibility of importing their manufactured goods instead of producing them locally (Agras & Chapman, 1997). Although emissions are likely to increase with income, EPI accounts for several other measures found to have monotonically improving relationship with economic growth (EPI, 2018), such as clean water and urban sanitation (Shafik & Bandyopahyay, 1992), that can offset the negative effect from increased emissions. Furthermore, as Tamazian et al. (2009) show, economic development is more likely to decrease environmental degradation at the higher income levels than at the lower income levels.

Studies overwhelmingly use GDP per capita as the measure for economic growth. While GDP is the most common measure for countries' wealth, it is limited in measuring well-being and development (Bérenger & Verdier-Chouchane, 2007). GDP might be better connected to the increased economic activity and thus show a positive relationship with CO_2 emissions, which are likewise connected to economic activity. However, human capital and life expectancy are tightly connected to the economic development but neglected by GDP. In this study, the income variable is replaced by human development index (HDI), which is constructed from GNI, human capital as years of schooling and returns on education, and health as both the life expectancy at birth and the life expectancy index (UN, 2018a). As argued by Torras and Boyce (1998), citizens of high-income countries are more likely to have more political power to demand stronger environmental regulation.

As already shown in Figure 1, GDP is limited at explaining differences between countries at similar income levels. Although HDI is expected to better capture the differences at each income level, there are other forces that are expected to explain differences in environmental performance. The literature suggests, that structural change, trade liberalization, FDI and government quality have an impact on the environmental performance. According to the literature, countries that are mainly agrarian, are expected to have better environmental performance due to low levels of industrial output (Panayotou, 1993). Countries with high manufacturing output are therefore expected to have higher levels of emissions, resulting in lower environmental performance. And thus, countries that have moved pass the manufacturing to the service-based economies are expected to have improved environmental performance. If the EPI follows a similar pattern to that of emission measurements, the expected relationship is similar to what the literature suggests. However, the results might show different magnitudes for the measured factors, given that the EPI includes indicators that are not expected to have a direct relationship with economic structure.

One of the biggest issues for global environment is the possibility that high-income countries relocate their ”dirty” industries to countries with weaker regulations (Agras & Chapman, 1997; Dasgupta et al. 2002). This would mean that greater openness to trade could in fact increase emissions at lower income levels, as high-income countries can import their products from lesser developed countries without causing pollution as a by-product themselves. To support the existence of the pollution haven hypothesis, openness to trade should improve environmental performance for high-income countries but decrease it for lower income countries. However, the relationship might not be as clear with EPI due to its complexity. The trade openness can additionally grow the economy, resulting in more environmental damage (Cole & Elliot, 2002), or alternatively put more pressure on adopting stricter regulation

(Grossman & Krueger, 1991). If pollution havens exist, the FDI should capture the industries locating in the low-income countries. However, FDI can also enable technology transfer to cleaner production methods, which was suggested by Grossman and Krueger (1991), and increases a country's income, which is associated with higher environmental performance. However, if trade openness is associated with the pollution haven hypothesis, received FDI should have a negative relationship with environmental performance.

The regulatory environment and quality of governance is likely to have a positive impact on environmental performance (Esty & Porter, 2005). Torras and Boyce (1998) found supportive evidence that literacy and political power have a positive impact on environment. Where governments are inefficient, it might be challenging to put forward more stringent regulations. Apostoaie and Maxim (2017) used the EPI and tested the relationship with government effectiveness. However, their study covered only the European Union (EU) member countries, and other factors, such as economic structure and trade, were not controlled. The government effectiveness is expected to be positively correlated with income, suggesting that at higher income levels, government effectiveness is higher, and therefore the effect of governance on environmental performance is expected to be stronger at higher income levels.

The empirical study aims to address the following hypotheses, derived from the literature. The hypotheses are largely based on earlier literature often using pollutants as dependent variable. While EPI does include several pollutants featured in earlier studies, it may not show as strong a relationship with pollution-related factors due to other environmental indicators included in the index. In the next section, the data on both environmental performance and the factors behind it are discussed in further detail.

H1. There is a positive relationship between country's economic development and its environmental performance.

H2. An increase in the share of agricultural output over GDP is associated with an increase in environmental performance.

H3. An increase in the share of manufacturing output over GDP is associated with a decrease in environmental performance.

H4. An increase in the share of service output in GDP is associated with an increase in environmental performance.

H5. Openness to trade has a negative effect on environmental performance at lower levels of income.

H6. Openness to trade has a positive effect on environmental performance at higher levels of income.

H7. Increase in the received FDI is associated with a decrease in environmental performance at lower income levels.

H8. There is a positive relationship between the quality of the government and environmental performance.

H9. High-income countries have a stronger positive impact from increased quality of the government than low-income countries.

3 Data

The data used for the empirical analysis combines figures from Yale University and Colombia University's Environmental Index (EPI, 2018), World Bank Group's World Development Indicators (WDI; World Bank 2017), Penn World Tables (2017), World Bank (2018a, 2018b, 2018c) and International Energy Agency's Key world energy statistics (2017). The variables included represent countries' economic performance and structure, government quality and environmental performance.

3.1 The sample

The data is cross-sectional by nature and does not include a time dimension. The data collected is not produced by sampling, but rather taking data for a full population, if available. The basic data for environmental performance covers 180 countries. Due to missing values in other measures, however, the final model is estimated with 148 countries, of which 47 are high-income, 42 upper middle-income, 37 lower middle-income and 22 low-income countries, based on the World Bank (2017) classification. Table 1 describes the data for the sample of 148 countries. The subsamples of income levels are discussed and presented in Tables 8 to 11 at the end of this section.

The lower observations in some variables are explained by missing observations. GDP per capita is used for comparative regressions, but two countries, Oman and Bahrain, had no GDP per capita measure available for 2016. The share of manufacturing output is missing for six countries, all from lower middle-income or low-income level. FDI received is used in the final estimation, but due to a negative value for inbound FDI, there are 10 observations missing. This is discussed further below. The omitted countries are often countries from lower income levels. Seven countries from low-income and 11 countries from lower middle-income countries are left out of the sample due to missing data. The most common missing values were in trade openness and sectoral shares. Considering these limitations, the data is biased toward high-income countries, given their higher share in the sample.

Table 1. The descriptive statistics of the sample

Variable	N	Mean	Std.Dev.	Min	Max
EPI	148	57.27	13.05	27.43	87.42
CO_2 per capita	148	0.74	1.62	-3.62	7.26
HDI	148	71.47	15.20	35.30	94.9
GDP (ppp)	146	9.37	1.18	6.66	11.76
Size of agriculture	148	12.45	12.24	0	59
Size of manufacture	142	13.22	7.04	0	43
Size of service	148	60.57	11.89	34	87
Government eff.	148	0.09	0.91	-1.64	2.21
Trade openness	148	4.34	0.51	3.09	6.01
FDI received	138	7.28	2.19	0	12.85
Pop.density	148	4.32	1.42	0.69	8.96
Urbanization	148	59.10	22.46	12	100

3.2 Environmental performance

The key variable in this thesis, and perhaps the most challenging to measure, is the environmental performance of a country. Environmental performance can be measured in many ways, and there is no commonly agreed upon single measurement. Most of the reviewed studies use single-pollutant measures, such as CO_2 and SO_2 emissions per capita. The data availability has been an issue throughout studies, and there are not many studies using global data from all continents. In this study, a sample covering countries from all continents and all income levels is used.

The environmental performance index gives a score from 0 to 100, which accounts for 24 different indicators for environmental performance, both from ecosystem vitality and environmental health. The report is issued by Yale University and Columbia University's Center for International Earth Science Information Network (EPI, 2018). The report has been published every second year for the past 20 years. All countries receive a score for all indicators, and the total index is calculated by a weighted sum of the indicators. EPI uses a variety of data sources, including international organizations, research institutes and government agencies. Data is selected based on its relevance, performance, methodology, verification, completeness and quality. The score for each indicator is calculated as distance-to-target. Individual scores are calculated by using equation (2), where x is the country's value, $\overline{x}$ is the target for best performance, and $\underline{x}$ is the target for worst performance (EPI, 2018).

$$Indicator\ score = \frac{x-\underline{x}}{\overline{x}-\underline{x}} \times 100 \qquad (2)$$

Values under the target for worst performance or over the target for best are given scores of 0 and 100 respectively. This can reduce the variability at the lowest and highest ends of the range. The final score is then calculated by weighting the individual scores and summing. As an example, for the $PM_{2.5}$ exposure, 86 countries exceed the target levels, giving them a score of 100 for the indicator. In contrast, 38 countries primarily from the low-income group fail to reach the minimum target for wastewater treatment, and thus receive a score of 0.

The EPI score is divided into two subcategories: Environmental health and ecosystem vitality, with weights of 0.40 and 0.60, respectively. These two main categories have further been divided into ten additional categories. Environmental is divided into air quality (0.65), water and sanitation (0.30), and heavy metals (0.05). Ecosystem vitality consists of biodiversity and habitat (0.25), forests (0.10), fisheries (0.10), climate and energy (0.30), air pollution (0.10), water resources (0.10), and agriculture (0.05). Each group is constructed from relevant indicators, listed fully in Appendix B. In table 2, the mean scores for each individual indicator are presented. Some of the sub-indicators are missing a value in every income level. Values for forests and tree cover loss are missing for countries such as Qatar, Saudi Arabia and Kuwait that are located mostly in desert, and small countries such as Antigua and Barbuda and Singapore. Values for fisheries are similarly missing for landlocked countries, such as those of Central Europe and Central Asia. Other variables, such as species protection and species habitat indices have missing values for mostly small island nations at all income levels, such as Malta, Maldives, Kiribati and Micronesia.

The mean values for the sub-indices reveal some interesting trends for environmental performance. First of all, while the overall EPI score is clearly higher for high-income countries, it is not true for all of its components. Strong upward trends are observed with environmental health, water sanitation and resources, drinking water, household solid fuels, lead exposure, methane emissions, black carbon emissions, nitrous oxide (N_2O) emissions and wastewater treatment. However, the trend is unclear or very weak for sustainable nitrogen management, CO_2 emissions, tree cover loss and both species protection and habitat indices. For tree cover loss, the trend seems to be the opposite. Low-income countries score better on average than high-income countries. One could find very weak evidence for EKC for biome protection and species protection habitat indices, which have higher scores at both high- and low-income levels, but lower at middle-levels.

Table 2. Means for EPI indicators summarized for different income levels.

Indicator	High (N=51)	Upper middle (N=51)	Lower middle (N=47)	Low (N=28)
Environmental performance	70.24	57.16	49.16	41.14
Environmental health	83.63	64.38	47.48	38.84
Ecosystem vitality	61.31	52.35	50.21	42.68
Air quality	84.52	70.66	54.92	52.76
Water and sanitation	83.22	52.56	32.15	9.87
Heavy metals	74.52	53.69	42.61	31.75
Biodiversity and habitat	79.79	64.19	62.28	67.61
Forests	18.65*	29.80*	29.45*	16.56*
Fisheries	54.35*	57.06	56.57*	58.92*
Climate and energy	54.53	48.58	52.34	39.48
Air pollution	57.06	50.50	46.68	42.10
Water resources	89.70	65.35	39.56	13.33
Agriculture	39.39	27.05	29.17	27.26
Household solid fuels	83.13	48.60	21.37	6.08
$PM_{2.5}$ exposure	84.68	84.86	76.47	83.15
$PM_{2.5}$ exceedance	86.22	85.89	78.11	84.60
Sanitation	84.14	85.89	31.54	9.60
Drinking water	82.31	51.19	32.76	10.14
Lead exposure	74.52	53.69	42.61	31.75
Marine protected areas	85.64*	76.21*	73.39*	55.44*
Biome protection (national)	81.53	60.09	61.56	69.03
Biome protection (global)	81.06	62.58	62.53	71.21
Species protection index	88.06*	66.20*	61.53*	71.48
Representativeness index	51.39	47.33	35.00	42.88
Species habitat index	83.60*	78.98*	73.91*	81.73
Tree cover loss	18.65*	29.80*	29.45*	16.56*
Fish stock status	59.53*	59.46*	70.06*	78.78*
Regional marine trophic index	49.17*	54.62*	43.08*	39.06*
CO_2 emissions – total	46.23	46.00	52.75	42.92
CO_2 emissions – power	54.51*	38.24*	46.65*	41.63*
Methane emissions	72.08	61.52	57.20	33.66
N_2O emissions	65.10	61.82	53.97	26.40
Black carbon emissions	63.68	48.01	46.78	17.04
SO_2 emissions	62.06	51.40	47.90	47.81
NO_x emissions	52.07	49.59	45.46	36.38
Wastewater treatment	89.70	65.35	39.56	13.33
Sustainable nitrogen management	39.38	27.05	29.17	27.26

*) missing observations

The strength of this data is the great variety it gives with a single numeric value as opposed to a single pollutant, used in most of the EKC studies. However, the EPI report is published every second year and the reports are not comparable with each other. Therefore, an attempt to build a panel using the index is infeasible. New reports always take advantage of the new technologies that allow better measurements of environmental performance and use the latest figures available. The 2018 report, for example, excluded measurement on environmental risk exposure due to difficulties in interpretation and levels of NO_2 as the data was no longer actively updated. (EPI, 2018). Despite the lack of longevity, the EPI score offers a great indicator for cross-country analysis, due to its comparability.

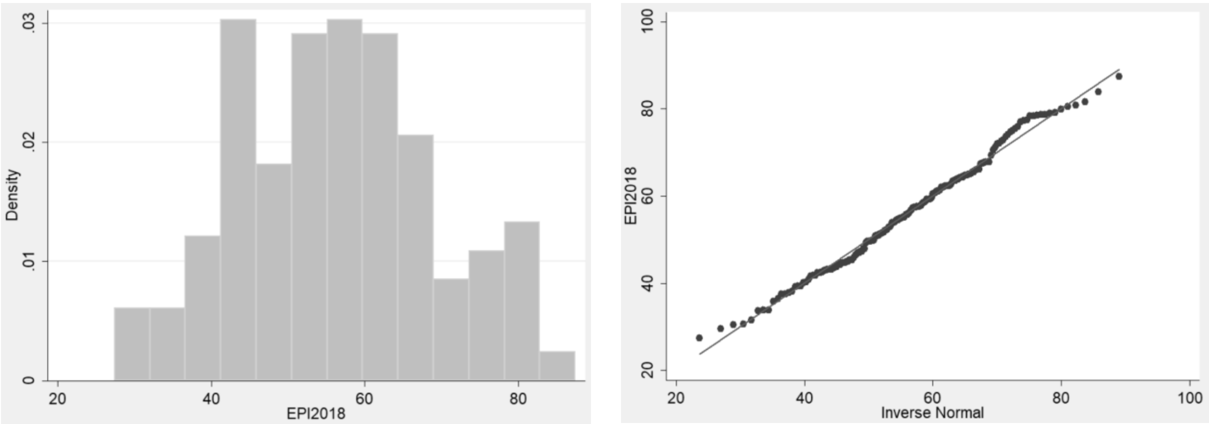

Figure 2. The distribution of EPI score, N = 180

The mean EPI score is 56.35, but there is a peak at lower values, and another peak around the mean value. Median value is slightly lower than the mean, 56.18. The highest EPI scores belong to Switzerland, France, Denmark, Malta and Sweden, respectively. High-income countries generally have scores well above the mean and hold the highest ranks in the scoreboard. At the high-income level, however, there are countries that score below the average. These are Barbados, Bahrain, Bahamas and Oman. From upper middle-income countries, the best scores are held by Costa Rica, Bulgaria, Turkmenistan, Albania and Colombia, and the worst by Angola, Bosnia and Herzegovina, Iraq and South Africa. Most of the lower middle-income countries have scores below the mean, with the exceptions of Morocco, Tonga, Tunisia, Armenia, Egypt, Sri Lanka, Philippines and Mongolia. Countries such as Bangladesh, India, Lesotho and Pakistan score well below the mean, and represent the worst performers of their income group. All of the low-income countries score below the mean. The best performers within the group are Senegal, Malawi, Guinea and Mozambique, with scores above 45, and the worst performers, with scores below35, are Haiti, Madagascar, Nepal, Democratic Republic of Congo and Burundi. At the lower scores, there is some overlapping between lower middle-income and low-income groups. The full set of countries together with their income classification and EPI scores is presented in Appendix C.

In addition to the environmental performance index, a more traditional measure of CO_2 emissions per capita is used for robustness checks of the model. This measure is provided by the IEA (2017), and it is measured as the metric tons of CO_2 divided by the population. Due to the non-linear nature of the variable and its high range, a logarithmic form is used. This causes some of the values that are less than zero to take on negative values (as seen in Table

1). The highest CO_2 emissions per capita are found in Cyprus, Qatar, Kuwait, Bahrain, United Arab Emirates and Saudi Arabia, respectively. The mean CO_2 emissions in high-income and upper middle-income countries exceed the sample mean. The lowest CO_2 emissions are found in low-income countries, many of which are excluded due to missing data. Burundi, Democratic republic of Congo and Chad have the lowest values of the sample. However, Somalia, Mali and Central African Republic have low levels of emissions but are not included in the sample.

3.3 Control variables

There are several possible independent variables that are used in earlier studies. To test the hypotheses stated at the end of the previous section, measures for economic development, sector sizes, trade openness and governance are needed. Below, the independent variables are introduced and discussed.

3.3.1 Economic development

Generally, the income variable included has been GDP per capita. However, GDP is not necessarily the best measure for development, as it measures only output that can be measured in monetary value. Unlike previous studies, this thesis utilizes the Human Development Index (HDI), which includes GDP, but additionallyincludes of human capital and life expectancy, which are important aspects of development. Table 3 shows, that HDI has higher correlation with EPI score than GDP. Furthermore, it will capture the effects of income and human capital, as it is highly correlated with these measures. GDP is gathered from the World Development Indicators (World Bank, 2017), human capital is from Penn World Tables (2017) and HDI is from the UN (2018a). Logged values are used for GNI and GDP, and HDI has been multiplied by 100 to match the scale of the EPI score, [0, 100]. Human capital is an index score based on years of schooling and return on education constructed by the Penn World Tables.

Table 3. Correlation matrix for development variables

	EPI	HDI	Log(GDP)	Human capital
EPI	1			
HDI	0.8625	1		
Log(GDP)	0.8258	0.9426	1	
Human capital	0.7924	0.8914	0.7947	1

One can see already in Figure 1 that the relationship between EPI and GDP appears linear. Below, Figure 3 illustrates the relationship between EPI and HDI, which appears to be strongly linear.

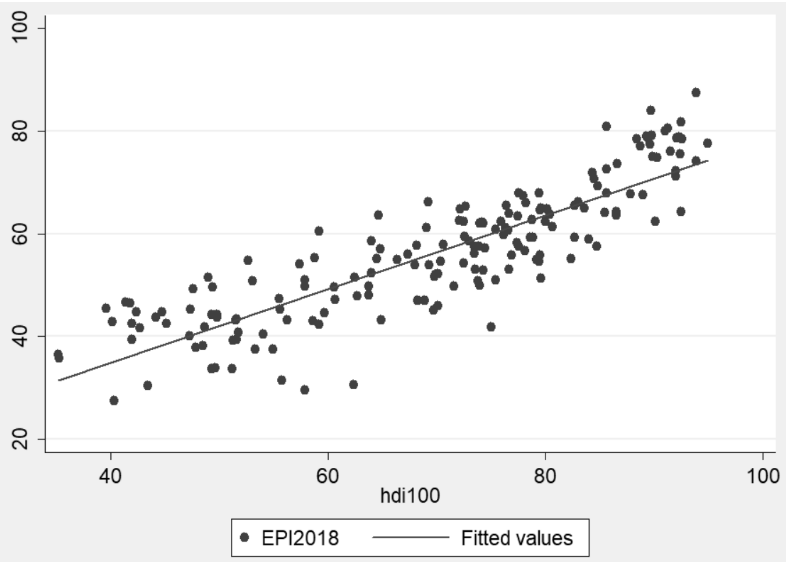

Figure 3 Relationship between EPI score and HDI.

3.3.2 Economic structure

One of the basic ideas of EKC is, that as a country grows, it shifts from agricultural to manufacturing, and from manufacturing to service-based economy (Grossman & Krueger, 1995; Panayotou, 1993). Increasing the manufacturing share of output corresponded to increasing emissions, as manufacturing tends to be more pollution-intensive than agricultural production. Advanced economies have further developed their industrial structure toward services and lighter industries, with lighter pollution intensities. The data is provided by WDI (World Bank, 2018a) to measure the relative sizes of agricultural, industrial/manufacturing and service sector. The relative size refers to the percentage of GDP that the sectoral output represents. Agriculture includes farming, fishing, hunting and livestock production. Industrial production includes both manufacturing and other industries, such as mining, construction, electricity, water and gas. Manufacturing share is also reported separately. Services include sales, trade, transport, governmental, financial, professional and personal services.

Table 4 presents the correlation of sectoral shares with environmental performance, and with each other. Agriculture has a strong negative correlation with EPI score, likely due to the tendency of mainly agrarian economies to be low-income countries, which have lower EPI scores. The correlation of agricultural output with HDI is strongly negative as well, meaning that the effect from agriculture might be caused by the income factor. The industrial sector seems to have no correlation with environmental performance. When examining only the manufacturing sector, the correlation is weak, but positive. The service sector has a clear positive connection to the environmental performance, but this might be due to the same reasons why the agricultural sector has a negative correlation. Service is positively correlated with HDI, which could imply that the income might explain the positive effect.

Table 4. Correlation matrix for economic structure

	EPI	HDI	Agriculture	Industry	Manufacturing	Services
EPI	1					
HDI	0.8625	1				
Agriculture	-0.6321	-0.7967	1			
Industry	0.0546	0.1800	-0.3729	1		
Manufacturing	0.1869	0.2721	-0.2207	0.3059	1	
Services	0.6013	0.6372	-0.6292	-0.4299	-0.0273	1

3.3.3 Trade openness

Openness to trade has been suggested to have a negative impact on environmental performance, particularly for developing countries, due to the pollution haven hypothesis, according to which industries with higher pollution-intensity will relocate themselves to countries with weaker regulation (Agras & Chapman, 1997). The openness to trade is measured as the sum of imports and exports over GDP. This figure is published by the World Bank (2018b). The ratio has been multiplied by 100 to present the percentage. In order to improve the linearity, a logarithmic form of the variable is used. Trade openness is missing for 22 countries, with majority (9) belonging to the lower middle-income group.

Another question often presented is the role of FDI on environmental performance. For this, data from WDI were collected, which has the net inflow of millions of US dollars. As 11 countries (Algeria, Bahrain, Belgium, Dem. Rep. Congo, Estonia, Hungary, Japan, New Zealand, Norway, Oman and Yemen) had negative values, a variable was constructed for received FDI, which omits the negative values. This allows transforming the variable into logarithmic form. The correlations among the variables are presented in Table 5. Trade openness shows only a weak correlation with environmental performance, and almost no relationship with FDI. However, FDI shows some positive correlation with environmental performance.

Table 5. Correlation matrix for trade variables

	EPI	HDI	Trade openness	FDI received
EPI	1			
HDI	0.8625	1		
Trade openness	0.2407	0.2702	1	
FDI received	0.4864	0.5449	-0.0516	1

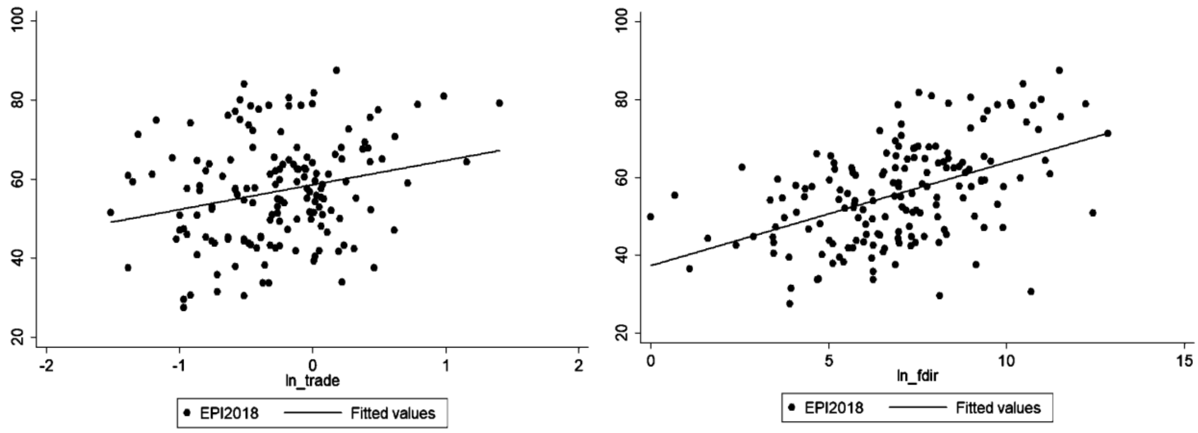

Figure 4. The relationship between environmental performance and trade openness on the left and received FDI on the right.

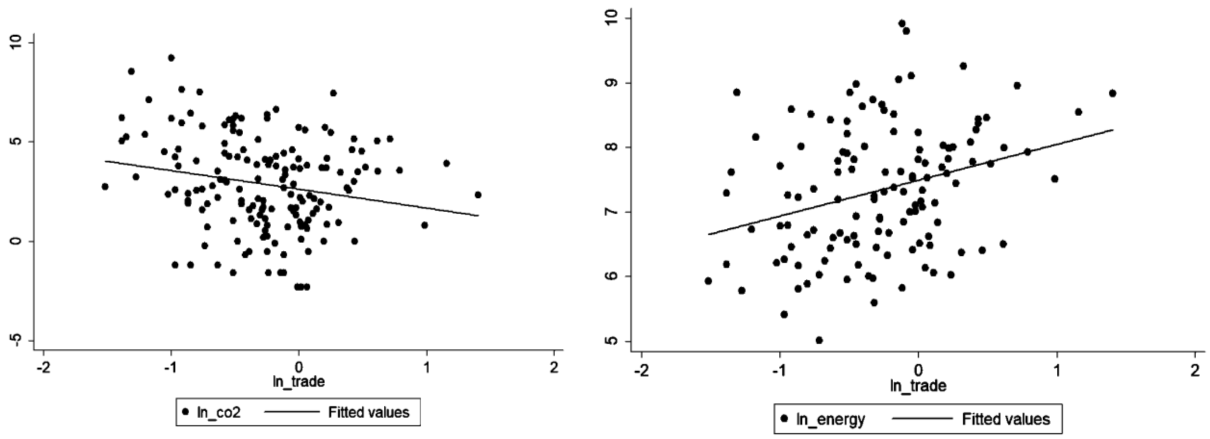

Figure 5. The relationship between openness to trade and CO_2 emissions (left), and energy use (right).

Both trade openness and FDI have a positive relationship with environmental performance. However, a graphical inspection shows, that it is only weakly linear (Figure 4). The relationship between trade openness and both total CO_2 emissions and energy use are presented in Figure 5. As can be seen from the graphs, trade openness has a more negative effect on emissions, and more positive on energy use. However, the correlation between trade openness and CO_2 emissions is rather weak (-0.21), and only slightly stronger with energy (0.31).

3.3.4 Government quality

Already in the early EKC literature, authors have suggested, that the government policies could explain, why environmental performance improves at higher levels of income (Grossman & Krueger, 1995). However, the government quality has largely been excluded from empirical analyses. The World Bank (2018c) publishes World Governance Indicators (WGI), which measure voice and accountability, political stability and absence of violence and terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption. Kaufman et al. (2010) constructed the indicators by using 31 data sources for over

200 countries. These indicators measure the overall quality of the government, and its policies and their effectiveness. The first variable, voice and accountability, measures how well citizens can participate through freedom of expression and media. Political stability measures the likelihood of government destabilization "by unconstitutional or violent means, including politically-motivated violence, and terrorism". By government effectiveness, the authors capture quality of the governmental institutions and policy implementation. Regulatory quality similarly measures the ability to stimulate private sector through sound policies. Control of corruption measures the "extent to which public power is exercised for private gain".

The World Bank governance indicators are scores between -2.5 and 2.5, approximately. The great advantage of the data is, that it is available for 180 countries in our sample. In Table 6 below shows that EPI is highly correlated with government effectiveness, regulatory quality, rule of law and control for corruption. However, the indicators are highly correlated with each other, potentially providing some methodological issues with empirical analysis.

Table 6. Correlation matrix for government policy variables

	EPI	HDI	Voice & accountability	Stability	Government effectiveness	Regulatory quality	Rule of law	Control for corruption
EPI	1							
HDI	0.8625	1						
Voice & accountability	0.5764	0.5306	1					
Stability	0.5764	0.5861	0.6550	1				
Government effectiveness	0.7882	0.8329	0.6865	0.7045	1			
Regulatory quality	0.7317	0.7607	0.7256	0.6472	0.9357	1		
Rule of Law	0.7338	0.7555	0.7409	0.7445	0.9493	0.9273	1	
Control for corruption	0.7313	0.7145	0.7394	0.7446	0.9178	0.8726	0.9422	1

The linearity between the environmental performance and governance indicators can be evaluated by examining the graphical representation of the bivariate relationships, presented in Figure 6. The linearity is weaker with voice and accountability and political stability indicators, but for indicators such as government effectiveness, regulatory quality and rule of law, linear models fit better. The latter indicators additionally form a strong linear relationship, when plotted together. Overall, countries with high levels of governance do have a better environmental performance as well. Government effectiveness has a stronger correlation with environmental performance, but additionally with other governance indicators. Due to potential multicollinearity issues, it is chosen as the sole indicator for quality of the government to further empirical testing. One of the potential issues is the high correlation with economic development, which may lead to multicollinearity.

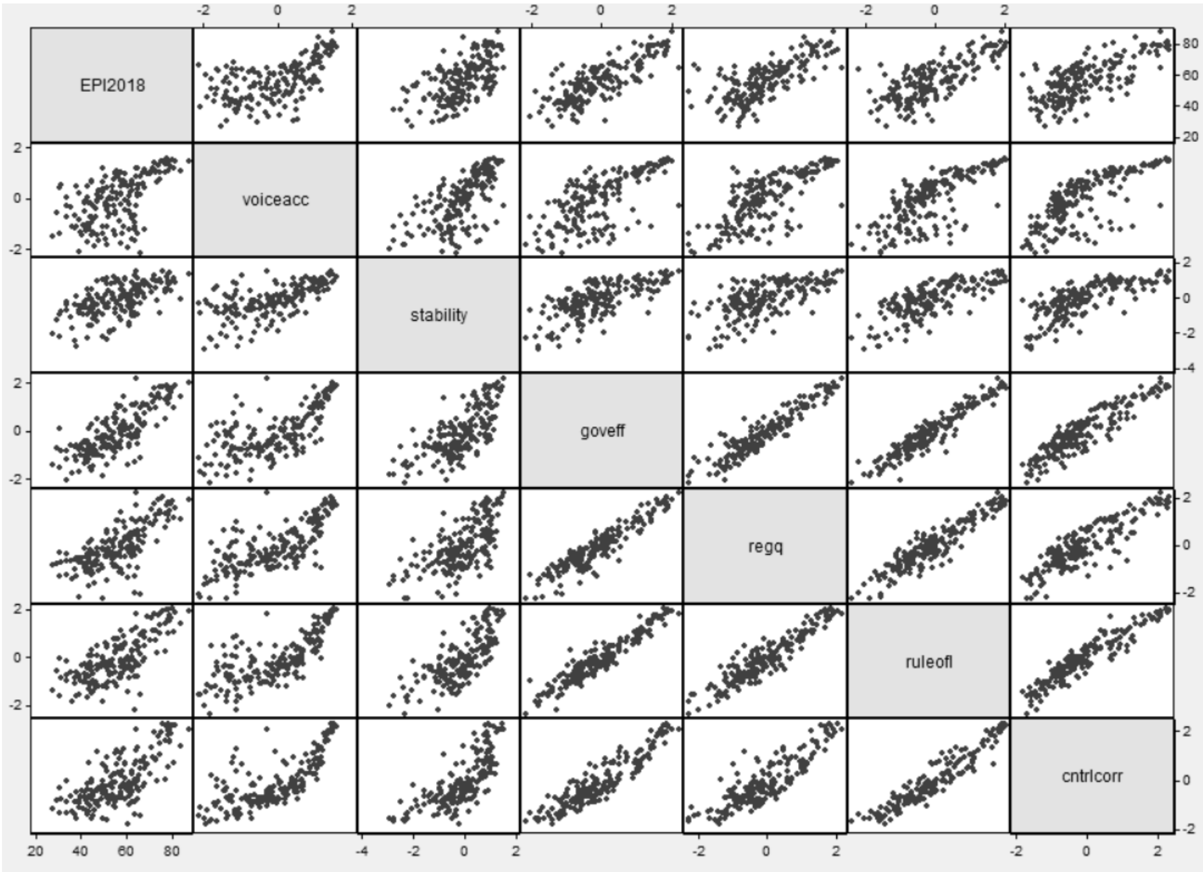

Figure 6. The relationship between the governance indicators and environmental performance

3.3.5 Other variables

Previous studies have often controlled for population density (Grossman & Krueger, 1991, Selden & Song, 1994), as higher density often implies higher emissions. However, countries with low density might still have urban centers that are highly populous. As can be seen from Table 7, urbanization is highly correlated with environmental performance, but population density only weakly. However, controlling for population density can be beneficial in further empirical analyses. Population density is population per square kilometer, ranging from 2 to 7807 in the sample, and urbanization is the proportion of population living in an area considered urban in each country, ranging from 0 to 100 (WDI, 2017). While the rate of urbanization forms a weakly linear relationship with EPI score, population density is neither normally distributed or linear, the logarithmic form is used in the study. The linearity is still weak, as indicated by the weak correlation, but the normality is significantly improved.

Table 7. Correlation matrix for population and urbanization

	EPI	Population density	Urbanization
EPI	1		
Population density	0.0829	1	
Urbanization	0.6575	-0.0155	1

3.3.6 Country classifications

In addition to the control variables presented above, countries are divided into groups presenting their income classifications. According to the World Bank classification, countries with GNI greater or equal to 12476 dollars (USD) are considered as high-income countries, whereas incomes ranging from 4036 to 12475 are upper middle income, 1026 to 4035 lower middle income and below or equal to 1025 low income countries. There are 51 high income countries, 51 upper middle income, 49 lower middle income, and 29 low-income countries in the EPI ranking. Two countries, Saint Lucia and Taiwan, are not included in the World Bank classification.

The below tables show the descriptive statistics for income groups separately. The EPI score is, on average, 29.1 points higher in high-income group than in low-income group. The standard deviation is the smallest in the lowest income group, where the scores are generally lower. HDI, unsurprisingly, has the highest average value in the high-income group. Low-income countries have the largest population on average, but urbanization is highest among higher incomes. The sectoral structure is heavily based on services among higher income countries, while lower income countries rely more on agriculture. The average size of the manufacturing sector is similar across the income groups. Both trade openness and received FDI tend to be higher with higher income. There are large differences in government effectiveness as well. While the average government effectiveness score for high-income countries is greatly positive, the scores for lower income levels are negative.

Table 8. High-income countries' descriptive statistics.

Variable	N	Mean	Standard dev.	Min	Max
EPI	51	70.24	8.65	51.32	87.42
HDI	51	87.06	4.75	78	94.9
Pop.density	51	4.57	1.54	1.10	8.96
Urbanization	51	75.96	18.84	8	100
Agriculture	50	3.1	5.23	0	36
Manufacturing	50	14	6.85	3	35
Service	50	70.08	10.52	42	89
Trade openness	48	4.55	0.57	3.30	6.01
FDI received	43	8.44	2.21	4.33	12.85
Gov.eff.	51	1.13	0.59	-0.18	2.21

Table 9. Upper middle-income countries' descriptive statistics.

Variable	N	Mean	Standard dev.	Min	Max
EPI	51	57.16	7.02	37.44	63.47
HDI	49	73.80	5.63	53.3	76.6
Pop.density	51	3.94	1.54	1.10	8.85
Urbanization	51	62.90	16.68	19	92
Agriculture	48	8.96	7.21	2	41
Manufacturing	49	13.06	7.61	2	43
Service	49	63.98	9.71	42	89
Trade openness	45	4.33	0.45	3.22	5.07
FDI received	49	7.36	1.89	3.58	12.43
Gov.eff.	51	-0.18	0.58	-1.89	0.96

Table 10. Lower middle-income countries' descriptive statistics.

Variable	N	Mean	Standard dev.	Min	Max
EPI	47	49.12	8.39	29.56	63.47
HDI	49	60.99	8.04	47.3	76.6
Pop.density	49	4.27	1.18	0.69	7.12
Urbanization	49	44.47	16.90	13	77
Agriculture	45	17.20	7.35	6	39
Manufacturing	41	13.12	6.62	0	33
Service	44	54.86	8.28	39	71
Trade openness	40	4.20	0.52	3.09	5.22
FDI received	47	6.20	2.23	0	10.69
Gov.eff.	49	-0.59	0.46	-1.82	0.49

Table 11. Low-income countries' descriptive statistics.

Variable	N	Mean	Standard dev.	Min	Max
EPI	28	41.14	5.95	27.43	50.83
HDI	29	46.18	6.42	35.2	66.6
Pop.density	29	4.26	1.12	2.079442	6.16
Urbanization	29	33.66	12.60	12	60
Agriculture	25	32.16	11.57	11	59
Manufacturing	21	8.19	4.31	2	19
Service	25	48.24	9.18	34	69
Trade openness	25	4.14	0.31	3.58	4.80
FDI received	28	5.27	1.76	1.10	8.26
Gov.eff.	29	-1.09	0.53	-2.18	0.11

4 Methods

The method used in this study is an econometric model, based on the standard EKC model used in previous studies. The model is based on the assumptions of classical linear model (CLM), discussed further in detail in Appendix E, and uses ordinary least-squares (OLS) estimators. As the data is cross-sectional, rather than a panel, there are some limitations to be addressed.

4.1 The Model

The model presented here is a linear regression model with environmental performance as dependent variable and several indicators as independent variables. Based on the theory, and further data examination, we assume, that the environmental performance is defined as:

$$EPI = F(D, S, T, G) \qquad (3)$$

Where D represents the economic development, measured here with HDI, S represents the structural change, measured as the sectoral shares of GDP, T presents the international trade, and G represents the government quality, measured by the efficiency of government. Furthermore, trade openness, which could affect the environmental performance through pollution haven hypothesis, population, and urbanization are controlled for. The basic regression model is a simplified version of the standard EKC model. However, since we do not anticipate an inverted U-shaped curve, due to the nature of our income variable and evidence of linearity of the environmental performance variable, we do not include quadratic or cubic forms of the income variable. The standard EKC model (1) generally has a time dimension, but due to the cross-sectional nature of the dependent variable, panel or time series regressions are not included in the model. The basic model is:

$$EPI_i = \beta_0 + \beta_1 HDI_i + \beta_2 Agr_i + \beta_3 Ser_i + \beta_4 Trade_i + \beta_4 FDI_i + \beta_5 Goveff_i + \beta_k Z_k + \varepsilon_i (4)$$

Where the HDI_i represents a country's economic development, Agr_i the share of agricultural output of the total output, Ser_i the share of service sector output, $Trade_i$ the trade openness as the share of combined exports and imports of total output, FDI_i the received net foreign direct investment, $Goveff_i$ the government effectiveness and the term $\beta_k Z_k$ represents the additional control variables, subject to each estimation, and ε_i is the error term for unobservable effects.

Before the estimation of the final model (4), which consists of EPI as the dependent variable and HDI, sectoral sizes, governance, trade, and urbanization and population density as the independent variables, the model is run with simpler estimations, to examine the relationships with environmental performance while allowing other variables to fluctuate. This will additionally identify any potential issues with robustness and provide more support for testing the hypotheses. For additional robustness checks, additional models are evaluated, allowing a comparison with more traditional variables. Model (5) replaces HDI by GDP per capita (GDP_i) and model (6) replaces the dependent variable by CO_2 emissions per capita (C_i). Model (7) includes both CO_2 emissions and GDP instead of more complex measures of environmental performance and economic development.

$$EPI_i = \beta_0 + \beta_1 GDP_i + \beta_2 Agr_i + \beta_3 Ser_i + \beta_4 Trade_i + \beta_4 FDI_i + \beta_5 Goveff_i + \beta_k Z_k + \varepsilon_i (5)$$

The purpose of including the GDP per capita variable is to examine, whether HDI captures some of the effect from other factors better or worse than the GDP measure. Additionally, the robustness of the model might depend on the measure of economic performance. These issues will be further discussed in the empirical section.

$$C_i = \beta_0 + \beta_1 HDI_i + \beta_2 Agr_i + \beta_3 Ser_i + \beta_4 Trade_i + \beta_4 FDI_i + \beta_5 Goveff_i + \beta_k Z_k + \varepsilon_i \ (6)$$

Due to the lack of studies using EPI as the dependent model, a comparison with a measure more commonly used could strengthen the results. Therefore, the final model will also be evaluated by using CO_2 emissions as the dependent variable.

$$C_i = \beta_0 + \beta_1 GDP_i + \beta_2 Agr_i + \beta_3 Ser_i + \beta_4 Trade_i + \beta_4 FDI_i + \beta_5 Goveff_i + \beta_k Z_k + \varepsilon_i \ (7)$$

The greatest limitation of the model is its non-dynamic nature, due to the missing time dimension. As discussed in the previous sections, the EKC is rather a dynamic process (Dinda, 2004), and that a global EKC is unlikely to exist (Stern & Common, 2001). Therefore, this study is unlikely to find any evidence of EKC. Rather, the focus will be on a cross-country analysis and comparison between different income levels and countries within similar income levels. Compared to earlier cross-sectional studies, the strengths of the method in this study are the large sample size and measures likely to capture the more complex nature of environmental performance and economic development.

5 Empirical Analysis

In this section, the empirical analysis and results for the models are presented. The robustness of the results is addressed throughout the analysis, but the full list of formal robustness check is included in the Appendix E together with the mechanics of each test. At the end of the section, the results are discussed and connected to the hypotheses stated at the end of Section 2.

5.1 Empirical results

5.1.1 Economic development and sectoral structure

The first five estimations test the hypotheses H1 to H4. First, the relationship with HDI and environmental performance is examined by controlling only the population density and urbanization. Table 12 presents the results from the regressions. As expected, economic development has a strong, positive and statistically significant impact on environmental performance. The effect is strongest, when controlling for the share of agricultural output, and weakest when controlling for the share of service output. Agriculture, despite having a negative correlation with environmental performance, shows a statistically significant positive relationship when controlling for economic development. However, controlling for agriculture alone increases the magnitude of economic development. Manufacturing output, however, does not show a relationship statistically significantly different from zero. Based on the weak correlation with EPI, this was expected. However, the result does not support the earlier arguments of manufacturing decreasing environmental performance. The share of service output has a statistically significant and positive relationship with environmental performance, and it does capture some of the effect from economic development. Holding the agricultural share constant, the service sector has a stronger impact on environmental performance. However, the effect from economic development is increased as well due to the impact from agriculture.

Table 12. Estimation results (1) to (5) for model (4)

	(1)	(2)	(3)	(4)	(5)
	EPI	EPI	EPI	EPI	EPI
N	175	165	158	165	164
Intercept	7.18040*** (2.74151)	-0.84434 (5.19843)	5.72941* (2.99630)	4.82558 (3.09589)	-7.82092 (5.74381)
HDI	0.65622*** (0.04343)	0.71950*** (0.06311)	0.68786*** (0.04833)	0.57681*** (0.05616)	0.64745*** (0.06427)
Pop.density	0.00909 (0.39679)	0.09720 (0.42254)	0.07312 (0.41150)	-0.15959 (0.42038)	-0.20781 (0.41112)
Urbanization	0.05740* (0.02954)	0.08099** (0.03171)	0.05562* (0.03122)	0.073818** (0.03158)	0.08670*** (0.03288)
Agriculture	-	0.14409** (0.06550)	-	-	0.20139*** (0.07774)
Manufacturing	-	-	-0.08609 (0.06689)	-	-
Services	-	-	-	0.12693** (0.05901)	0.20322*** (0.05548)
R^2	0.7479	0.7512	0.7546	0.7529	0.7679

Statistical significance: p-value: *** <0.01, ** <0.05, * <0.10. Robust standard errors in parentheses.

The first estimations, however are not robust to the assumptions of CLM. While the residuals follow normal distributions to a satisfactory confidence level (see table E for detailed robustness check results), there are issues with heteroskedasticity and omitted variable bias. Heteroskedasticity has been addressed by using heteroskedasticity-robust standard errors, as suggested in Wooldridge (2012). However, omitted variable bias is a result from misspecification. The model does not include all relevant variables. Thus, by only including economic development and sectoral structure does not explain environmental performance at a satisfactory level. This is addressed at the final stages, where sectoral structure is combined with other relevant factors.

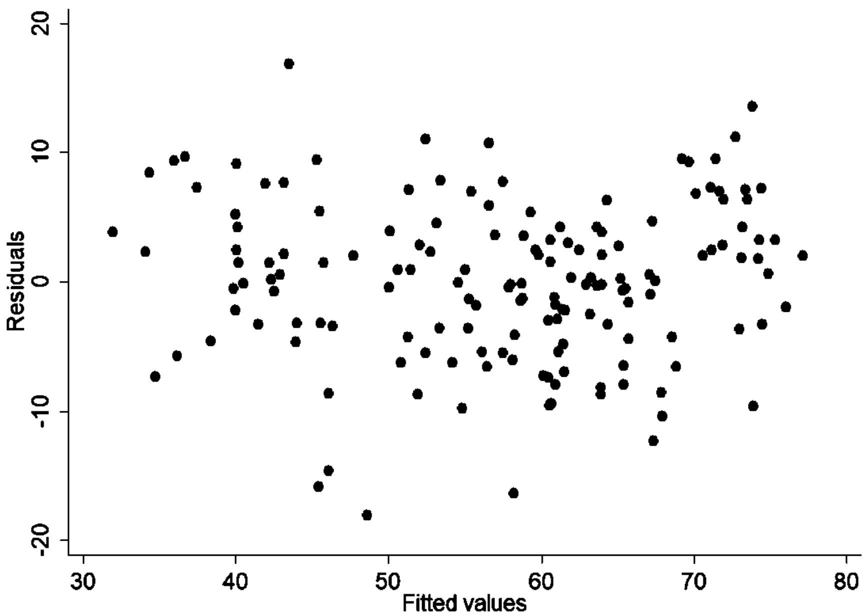

Figure 7. Plot of residuals and fitted values for estimation (5)

Heteroskedasticity can rise from misspecifications of the model and outliers. The plotted residuals and fitted values (Figure 7) show, that some observations lie well below and above the zero-mean. Countries with large negative residuals are India, Bosnia and Herzegovina, Bangladesh, Nepal and Bahamas. The only immediately apparent common factor is the below-average environmental performance. Countries with large positive residuals are Equatorial Guinea, Switzerland and France. The latter two have the highest environmental performance of the sample and exceed the average performance of countries at similar income level. Equatorial Guinea, however, has a low HDI compared to other countries at similar income level, but it has above-average environmental performance.

5.1.2 Trade and environmental performance

Earlier studies have found mixed evidence of whether trade liberalization is good for the environment. Trade openness can drive companies to relocate their manufacturing activities to countries with weaker regulations. This would result in weaker environmental performance as trade openness increases at lower income levels but could improve environmental performance at higher levels. To test hypotheses H5 and H6, the sample is divided into subsamples of high-income (HI), upper middle-income (UMI), lower middle-income (LMI) and low-income (LI) countries. The hypothesis H7 examines, whether increased FDI received at lower income levels would result in worsening environmental performance and thus would reveal evidence of pollution havens. Therefore, the variable for received FDI is added to the estimations. Interestingly, there are seemingly no connection between trade openness (*ln_tr*) and FDI, as shown in Figure 8. Thus, the evidence for FDI causing more or less exports could be weak.

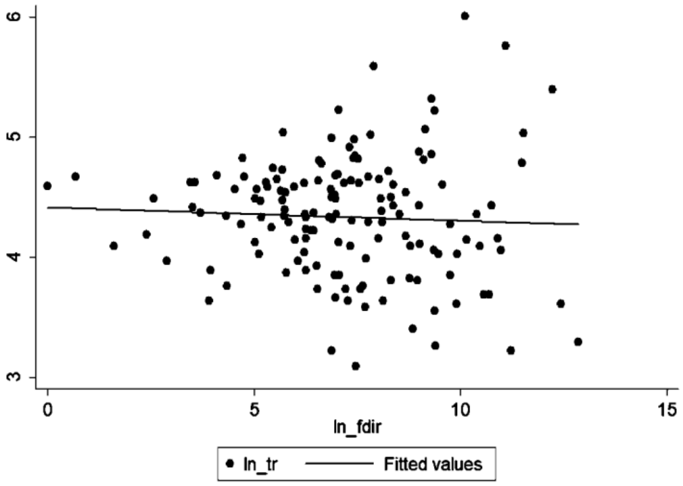

Figure 8. Relationship between trade openness and FDI

Table 14 presents the estimation results for trade and FDI, controlling for economic development, population density and urbanization. As in earlier equations, population density and urbanization do not show a statistically significant relationship with environmental performance. HDI is statistically significant and positive for higher income levels, but at the lowest level, the impact is rather small and due to high standard error, statistically insignificant. Interestingly, the HDI experiences strongest positive relationship at the highest income level, supporting the findings of Tamazian et al (2009). At each income level, trade openness does not show any statistically significant relationship with environmental performance. However, there is some evidence, that received FDI has a statistically significant, negative relationship with environmental performance at lower-middle income level. However, the number of observations at each income level are low. Robustness checks do not indicate issues with normality of residuals, heteroskedasticity, or multicollinearity. Omitted variable bias is present for estimation (7).

Table 13. Estimation results (6) to (9) for model (3)

	(6)	(7)	(8)	(9)
	EPI (HI)	EPI (UMI)	EPI (LMI)	EPI (LI)
N	40	42	39	23
Intercept	-55.54111* (28.21721)	12.42849 (19.62998)	17.6524 (14.10281)	23.96157 (23.63616)
HDI	1.486152*** (0.3657709)	0.516143** (0.232769)	0.7526686*** (0.1453835)	0.1618235 (0.3657961)
Pop.density	0.1987979 (0.92654)	0.5807343 (0.5070091)	-1.007984 (1.182431)	-0.6619629 (1.504659)
Urbanization	-0.0360527 (0.0635183)	0.1217338 (0.0807805)	0.0830213 (0.0626832)	0.0624556 (0.1548168)
Trade	0.2751058 (2.073152)	-0.1775403 (1.806073)	-1.993583 (2.260235)	1.143891 (4.747874)
FDI	-0.3205634 (0.6749795)	-0.3699824 (0.4931938)	-0.9511909** (0.4532728)	1.134676 (1.058179)
R^2	0.4842	0.3843	0.5414	0.1631

Statistical significance: p-value: *** <0.01, ** <0.05, * <0.10. Robust standard errors in parentheses.

Due to the overlapping and unequal shares at the income levels, the estimations (6) to (9) are rerun by using an alternative income classification that enables overlapping due to differences in purchasing power. Thus, countries are classified more evenly based on their GDP per capita in ppp-corrected international dollars, instead of the World Bank classification. Changing the classification puts more countries into the low-income level. Countries such as Kenya, Ghana, Micronesia, Cameroon, Lesotho, Kyrgyzia, Mauritania, Zambia, Sudan, Bangladesh, Cambodia and Kiribati are dropped into the lowest quartile, although classified as lower-middle income countries by the World Bank. Several upper middle-income countries are dropped to the lower middle-quartile, and high-income countries to the upper middle-quartile. The highest quartile remains similar to the World Bank classification, with exceptions of Malaysia and Equatorial Guinea, which are classified as upper middle-income countries.

The results presented in Table 14 show similarities with the results in Table 14. Trade openness remains statistically insignificant at all income quartiles. FDI shows a negative relationship with environmental performance at the lower-middle quartile, but the statistical significance is slightly lower than with World Bank classification. HDI now shows a statistically significant relation at all levels. Interestingly, population density has a statistically significant positive relation at upper middle-quartile and urbanization at lower middle-quartile. All estimations do pass the tests for normality of residuals, omitted variable bias and multicollinearity. Heteroskedasticity is only present at the estimation (13). This is likely due to the greater variety of countries included at the quartile.

Table 14. Estimation results (10) to (13) for model (4)

	(10)	(11)	(12)	(13)
	EPI (HI[1])	EPI (UMI[1])	EPI (LMI[1])	EPI (LI[1])
N	36	36	35	36
Intercept	9.871013 (23.28312)	-18.76937 (22.38592)	10.69374 (12.73241)	31.26408** (13.35085)
HDI	0.7658281** (0.2942958)	0.8961536*** (0.2244925)	0.6731997*** (0.1905681)	0.4061616*** (0.143594)
Pop.density	-0.0469008 (0.8773369)	1.032126** (0.4659167)	-0.4102418 (0.9667904)	-2.04354 (1.259451)
Urbanization	-0.0781283 (0.0919647)	0.086576 (0.0528663)	0.1680716** (0.0801207)	0.0126037 (0.0811331)
Trade	-0.1448996 (2.266722)	0.0367884 (2.139941)	-0.834695 (2.159702)	0.1476728 (2.778554)
FDI	0.2563738 (0.6817902)	-0.1850885 (0.5924847)	-1.037803* (0.5743732)	-0.1158637 (0.5818696)
R^2	0.3432	0.4545	0.5321	0.2353

Statistical significance: p-value: *** <0.01, ** <0.05, * <0.10. Robust standard errors in parentheses.
1) as per alternative classification based on GDP per capita in ppp-dollars

5.1.3 Government quality and corruption

Table 16 presents the results for estimations (14) to (16). To test hypotheses H8 to H9, the quality of governance is added first as a coefficient for full population in estimation (14), and as a categorical coefficient for estimation (15). Both estimations control for HDI, population density and urbanization, as in previous estimations. For further pollution haven hypothesis analysis, estimation (15) controls for both trade openness and received FDI.

Estimation (14) shows, that overall, government effectiveness has a statistically significant and positive relationship with EPI. This result, however, has issues with both heteroskedasticity and omitted variable bias. Estimation (15) fixes the issue with omitted variable bias by introducing income level-specific coefficients. It also reveals, that the relationship between government effectiveness and environmental performance is only statistically significant at the highest income level. However, the estimation results do not pass the test for normality of residuals. Estimation (16) controls for trade openness and FDI received. As in previous estimations, trade openness and FDI received do not have any statistically significant relationship with environmental performance. However, the coefficients for HDI and government effectiveness at high-income levels are slightly increased. However, due to missing observations in trade openness, this could be explained by removing outliers. The normality of residuals is passed in formal test. All estimations have issues with heteroskedasticity, which is addressed by using heteroskedasticity-robust standard errors.

Table 15. Results for estimations (14) to (16)

	(14)	(15)	(16)
	EPI	EPI	EPI
N	175	175	144
Intercept	19.43973*** (3.979936)	16.48797*** (4.928763)	16.43546** (7.117161)
HDI	0.4894462*** (0.0638168)	0.5209174*** (0.0745729)	0.5318524*** (0.0870297)
Pop.density	-0.1636937 (0.3907853)	-0.1071368 (0.4206178)	-0.1877598 (0.4688428)
Urbanization	0.0616272** (0.029883)	0.0459457 (0.0311213)	0.0579169 (0.0384125)
Government effectiveness	3.192154*** (0.9342511)	-	-
Gov.eff. (HI)	-	4.865864*** (1.166811)	5.190446*** (1.305882)
Gov.eff. (UMI)	-	0.5741295 (1.873101)	1.443594 (2.553936)
Gov.eff (LMI)	-	1.090173 (2.019125)	1.176203 (2.477395)
Gov.eff. (LI)	-	0.7274233 (1.997944)	0.4289092 (2.296266)
Trade openness	-	-	-0.0285328 (1.270996)
FDI received	-	-	-0.1604104 (0.2925913)
R^2	0.7653	0.7756	0.7743

Statistical significance: p-value: *** <0.01, ** <0.05, * <0.10. Robust standard errors in parentheses.

Figure 9 shows the existence of outliers. India, Bangladesh, Singapore, Bosnia and Herzegovina, Nepal and Chile all have strongly negative residuals, while Equatorial Guinea has strongly positive. From these countries, Singapore has a high level of government effectiveness, compared to the average of its income level. Equatorial Guinea's government effectiveness is greatly lower than the average of the income level. India and Bangladesh score slightly above and below the average, respectively. Estimation (16) excludes 31 countries with a mean government effectiveness (-0.28) lower than the full population mean (-0.06), due to missing values in trade openness and received FDI. Therefore, the results from estimation (16) are slightly biased toward countries with higher government effectiveness value.

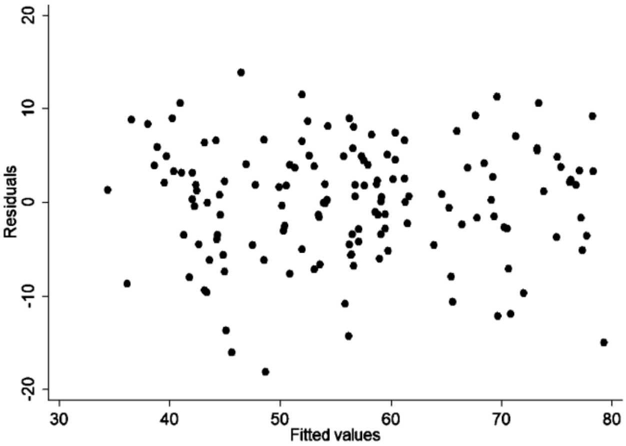

Figure 9. Residual plot for estimation (14)

5.1.4 Final model

The estimations so far have examined the relationships with individual factors of environmental performance. In the final model, the factors identified from literature are combined in model (4), following the function of EPI, which was assumed to follow equation (3), and compared with alternative measures by using models (5) to (7). Estimation (17) shows signs of heteroskedasticity, which is connected to the received FDI. By omitting FDI, the estimation (18) passes the formal test of homoskedasticity. FDI, however, captures some of the effect from government effectiveness, but otherwise the results remain similar. FDI itself does not show any statistically significant relationship with EPI. When introducing income level-specific coefficients for government effectiveness in estimation (19), the effect is again found to be statistically significant only at the high-income level. However, adding the categorical variables to the estimation increases heteroskedasticity, making the estimation less efficient overall. In all estimations, however, heteroskedasticity-robust standard errors are used. Estimation (20) replaces HDI by GDP per capita measure, for an additional robustness check. This reveal, that the HDI captures better the impacts from structural change, in this case, relative increases in either service or agricultural outputs, and government effectiveness. GDP per capita variable itself has a statistically significant and positive effect on EPI. However, heteroskedasticity becomes an issue in the estimation. Estimation (21) replaces EPI with CO_2 emissions. This shows that the HDI has a positive relationship with CO_2 emissions. Finally, estimation (22) compares the findings with the standard EKC model, with CO_2 emissions per capita as the dependent variable. The estimation has issues with both normality of the residuals and heteroskedasticity. This indicates, that the results are not robust to the CLM assumptions. Econometrically the strongest estimation is (18). This estimation passes the Gauss-Markov assumptions and additionally the assumption of the normally distributed error term. Thus, it can be considered as CLM.

Table 16. Results for estimations (17) to (22)

	(17)	(18)	(19)	(20)	(21)	(22)
	EPI	EPI	EPI	EPI	CO_2	CO_2
N	138	148	148	148	149	149
Intercept	-3.22400 (7.72281)	-0.07373 (7.88661)	0.67119 (8.55442)	-18.36034 (11.64522)	-6.45856 (1.11487)	-11.41127*** (1.45392)
HDI	0.52592*** (0.08896)	0.53392*** (0.08678)	0.54390 (0.10019)	-	0.08599*** (0.00941)	-
GDP per capita	-	-	-	5.55707*** (1.10418)	-	1.12104*** (0.12184)
Pop.density	-0.43361 (0.46862)	-0.39149 (0.44186)	-0.36101 (0.46783)	-0.33846 (0.48403)	-0.06358 (0.04190)	-0.08222* (0.04290)
Urbanization	0.07951** (0.03803)	0.08250** (0.03494)	0.06507* (0.03778)	0.08411** (0.03958)	0.00514 (0.00381)	-0.00028 (0.00385)
Service	0.18163*** (0.05664)	0.18760*** (0.05970)	0.17864*** (0.05863)	0.26358*** (0.06452)	0.00195 (0.01344)	0.023527* (0.014497)
Agriculture	0.19389** (0.07779)	0.20676** (0.07890)	0.17734** (0.07349)	0.20189*** (0.06790)	-0.02458*** (0.00924)	-0.01394 (0.00903)
Trade openness	0.97980 (1.24635)	0.41502 (1.13337)	0.25463 (1.12263)	0.26353 (1.22717)	0.28901** (0.11469)	0.18081 (0.1415532)
FDI received	0.31947 (0.30230)	-	-	-	-	-
Government effectiveness	2.44933** (1.14728)	2.90427*** (1.09081)	-	3.96983*** (1.117359)	-0.39401*** (0.11403)	-0.33404*** (0.096335)
Gov. effect. (HI)	-	-	4.29186*** (1.23838)	-	-	-
Gov. effect. (UMI)	-	-	-0.16649 (2.79983)	-	-	-
Gov. effect. (LMI)	-	-	1.00713 (2.24962)	-	-	-
Gov. effect. (LI)	-	-	1.09938 (2.40805)	-	-	-
R^2	0.7755	0.7866	0.7941	0.7679	0.7666	0.7785

Statistical significance: p-value: *** <0.01, ** <0.05, * <0.10. Robust standard errors in parentheses.

The predicted values for estimation (18) reveal some outliers. Equatorial Guinea has the greatest residual from the sample. It has the EPI score of 60.4, which is greater than its predicted value of 40.73 based on its performance on other indicators. Comparing to countries in similar income levels, it has low scores on government effectiveness and a low HDI. India, Bangladesh and Bosnia and Herzegovina present the other kind of outliers, performing worse than their performance eon other indicators would predict.

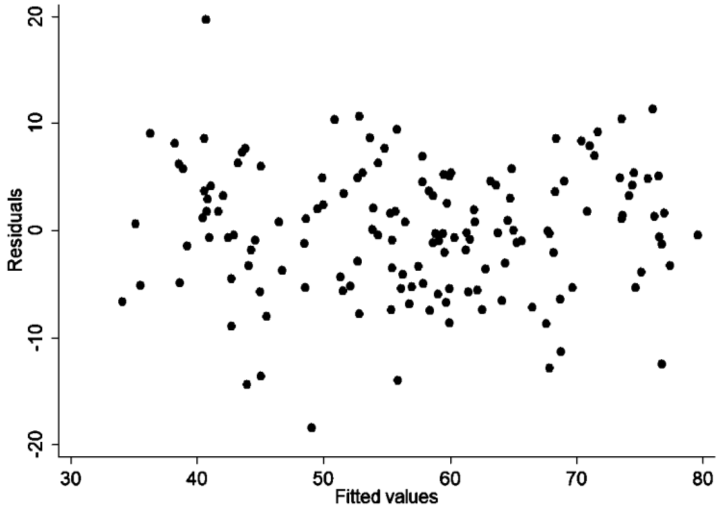

Figure 10. Residual plot for estimation (18)

The findings suggest, that economic development has a statistically significant positive relationship with environmental performance, thus confirming hypothesis H1. A unit increase in HDI is associated with an increase of 0.53 units in EPI. Compared to the GDP per capita measure, it captures better the effect from service transition and government effectiveness. Additionally, by using HDI instead of GDP per capita, the null-hypothesis for homoskedasticity was rejected, thus improving the robustness of the results.

5.2 Discussion

5.2.1 Summary of findings

The relationship between economic development and environmental performance has been examined in a cross-country comparison, including 148 countries spanning all income levels around the world. Environmental performance, measured as EPI, was found to be stronger at higher income levels. The average scores of the EPI indicators were generally higher in the high-income group. However, as some exceptions show, the level of income does not always indicate higher performance. CO_2 emissions were found to have the highest scores at lower middle-income countries, indicating lower total emissions. Another commonly measured pollutant, SO_2, had higher performance at high-income level, but the differences in average scores did not indicate a strong trend. The trend is stronger for environmental health than ecosystem vitality related indicators. In particular, the water safety and wastewater treatment cause greater issues for low-income countries, while most of the high-income countries passed the target levels.

The expectations for the relationship between economic development and environmental performance were positive, despite mixed evidence found in earlier studies for economic growth increasing emissions (Shafik, 1994; Tsurumi & Managi, 2010). Studies examining the existence of EKC have assumed the relationship between emissions and growth to change over time. While in this study, there is no time dimension to verify, whether economic development has caused improvements in environmental quality over time, the results indicate, that development is positively associated with environmental performance at all income levels. A unit increase in HDI is associated with an increase of 0.53 units in EPI, thus confirming hypothesis H1. Compared to the GDP per capita measure, it better captures the effect from service transition and government effectiveness. Additionally, by using HDI instead of GDP per capita, the null-hypothesis for homoskedasticity was rejected, thus improving the robustness of the results. For CO_2 emissions, the findings suggest a positive relationship. A unit increase of HDI corresponds to 8.6-percent increase in CO_2 emissions per capita. Similarly, a one-percent increase in GDP per capita corresponds to 1.12-percent increase in CO_2 emissions. Thus, it seems likely that other measures captured by the EPI offset the negative impact on CO_2 emissions by economic development.

Hypotheses H2 to H4 examined the relationship between structural change and environmental development. As hypothesized by the EKC literature, industrial development could cause emissions to increase, as the share of manufacturing output increases. However, this development would eventually decrease emissions as the share of services outgrows the manufacturing sector. This study does not find any statistically significant relationship between manufacturing output and environmental performance. Thus, hypothesis H3 can neither be confirmed nor rejected. Literature suggests, that manufacturing is connected to the increased emissions, which is only one part of the EPI. It seemingly has no effect on the broader environmental quality. Agricultural output has a statistically significant and positive relationship with environmental performance, which is stronger when controlling for service output. In reverse, this could indicate, that shifting from agriculture to manufacturing could decrease the environmental performance. When examining the relationship with CO_2 emissions, the agricultural share only has a statistically significant negative relationship when controlling for HDI instead of GDP. However, hypothesis H2 can be confirmed due to the identified positive impact of relative size of agricultural output on HDI. An increase of service output has found to be statistically significant and positive when controlling for agriculture. Therefore, the growth of service output would result in a declining share of industrial output. The effect is found to be positive when examining CO_2 emissions, but it can be considered statistically significant only when controlling for GDP. HDI is found to capture some of the effect from service transfer, possibly explaining the weak positive effect on CO_2 emissions. Like hypothesis H2, hypothesis H4 can be confirmed due to the statistically significant positive relationship found between the share of service sector output and environmental performance.

The declining share of manufacturing output can be alternatively connected to relocation of pollution-intensive activities to countries with weaker regulations, also known as pollution havens. Studies so far have found mixed evidence. In this study, the relationship was examined by using trade openness and received FDI to capture possible relocation. Trade openness, however, is not found to have any statistically significant relationship with environmental performance at any income level. This could be attributed to the complexity of the measure, as pollution havens are mostly connected to energy use and emissions. Thus, hypotheses H5 and H6 cannot be confirmed. Likewise, the relationship between FDI and environmental performance is questionable. While the overall sample does not show any statistically significant relationship, there is some evidence of FDI affecting environmental performance negatively at the lower middle-income level. Thus, there is some support for H7, but the results are not strong enough to confirm it. Furthermore, this study finds some evidence of openness to trade having a positive impact on CO_2 emissions, as shown in estimation (17). However, after controlling for GDP instead of HDI, this effect becomes statistically insignificant.

The quality of government was expected to have a positive relationship with environmental performance. The political economy was found to impact the environment, and governments play a key role in affecting, how the public power is used. Although government effectiveness does not necessarily imply better environmental performance, effective governments can be expected to address environmental issues more efficiently than ineffective governments (Apostoaie & Maxim, 2017). Additionally, government effectiveness was found to be highly correlated with other measures of governance, such as corruption control and regulatory quality, both of which are important for the effectiveness of environmental regulation. This study finds a statistically significant and positive relationship between government effectiveness and environmental performance. A closer examination at the different income levels revealed that the effect was stronger and statistically significant at the high-income level, but not in lower income levels. Hypotheses H8 and H9 thus can be confirmed.

5.2.2 Theoretical implications

Understanding the relationship between economic development and environment is crucial in designing policies that would raise people and countries out of poverty without creating irreversible environmental damage (Grossman & Krueger, 1995). Earlier studies have been based strongly on the assumption of worsening environmental quality at earlier stages of development, and improving at later stages (Grossman & Krueger, 1991,1995; Shafik & Bandyopadhyay, 1992; Panayotou, 1993, among others). Some evidence, however, has suggested a monotonic increase in emissions, thus worsening environmental quality at any given increase in economic development (Shafik, 1994; Azomahou et al. 2006). Most of the studies so far have taken environmental performance as a concentration of emissions and found a positive relationship with economic growth. However, as the EPI (2018) report shows, the relationship between income and environmental performance can be more positive when measuring the environmental quality with a more complex measure. In this study, the theories from previous studies applied to simple measures of environmental quality were combined with a new, more representative measure. The findings suggest more optimistic results. Economic development, measured as the combination of GDP, human capital and public health can be connected to better environmental health and ecosystem. Economic development should, however, be considered as more complex than solely income. GDP measures the monetary value of domestic outputs, which could be linked to increased emissions through increased economic activity. As Torras and Boyce (1998) suggested, literacy is related to decreases in emissions, and thus it is worth considering the role of human capital as a part of the development. The role of public health can be bi-directional, as worse air quality can lead into worsening public health and lost years in life expectancy (EPI, 2018). This study confirmed a positive relationship between HDI (which includes income, human capital and life expectancy) and environmental performance, but cannot confirm which way the causality runs. Earlier studies have examined the Granger causality and found mixed results depending on the context. Environmental quality can have significant effects on economic development, as bad air quality is already connected to decreased life expectancy, especially at lower income levels (EPI, 2018). Environmental damage can also hinder economic development by decreasing the value of natural resources (Arrow et al. 1995). Therefore, policymakers should be careful when interpreting the effects of economic development.

Other factors included by earlier studies were structural change, international trade and the role of government (Dinda, 2004). The idea of structural change driving the environmental performance was derived from the original Kuznets curve hypothesis (Kuznets, 1955; Grossman & Krueger, 1991; Panayotou, 1993). The relative increase and decrease of the manufacturing sector has had a key role in explaining the concentration of various emissions, such as CO_2 emissions connected to energy consumption (Panayotou, 1993; EPI, 2018). However, manufacturing does not have a direct relationship with other environmental indicators. While the relative shares of agricultural and service sector outputs do show a positive relationship with environmental performance, the study does not identify the mechanism. There could be additional underlying explanations as to why a country with a bigger service sector has, on average, a better environmental performance than a country with similar economic development and a smaller service sector.

International trade can relocate emissions from one country to another (Dinda, 2004). This study cannot confirm any statistically significant relationship between trade openness and environmental performance. This does not necessarily mean, that there would not be positive or negative effects from trade. As argued by Grossman and Krueger (1991), penalizing countries for trading by increasing tariffs or introducing non-tariff trade barriers could hinder the economic development of a country. People with higher incomes can afford to value the environment more (Dasgupta et al. 2002; Dinda, 2004), and thus may demand transparency for the carbon footprint of the imports, creating pressure for exporting countries to reduce emissions. Trade openness is not necessarily the best way to capture the effects of trade, if they work through the scale, technique and composition effects (Cole & Elliot, 2002). Scale effects would be captured by increased economic activity, technique effects through technological change and composition by economic structure. Furthermore, the complexity of environmental performance may not support the idea of trade openness having a directly observable relationship. The study found a positive relationship between carbon emissions and trade openness, but it is sensitive to the model specification. While there might be evidence of pollution havens for carbon emissions, that is not necessarily the case for broader environmental quality.

Government actions were raised by many scholars as crucial for improving environmental performance. However, the lack of internationally comparable measures for environmental regulations is a severe hindrance to more sophisticated analysis. This study has relied on the likely correlation between government effectiveness and its ability to regulate the environment. Earlier studies have found positive relationships between several political indicators and overall democracy, and environmental performance (Torras & Boyce, 1998; Dasgupta et al. 2001; Frankel & Rose, 2005; Esty & Porter, 2005). Thus, it seems likely, that countries with effective governments are more able to control their environmental damages as well. In this study, the government effectiveness was found to have a positive relationship with environmental performance, and negative with CO_2 emissions. However, whether this is achieved by relocation of pollution-intensive activities or by improving technologies and standards, is beyond the scope of this study.

6 Conclusion

This study aimed to further examine the factors behind the relationship between economic development and environmental performance. The study was motivated by the lack of a broader, more representative measures of environmental performance and economic development. Earlier studies have been criticized for using only a few indicators, often air pollutants, for environmental degradation and small and geographically limited samples (Fiorino, 2011). This study addresses this gap by using a broader and more complex metric for environmental performance, and by including a large sample of 148 countries across the globe. Through identifying the most common factors from previous literature, this study has found economic structure, international trade and government effectiveness to be the likely drivers of the differences in environmental performance at similar incomes. The empirical results revealed, that while international trade has no direct relationship with environmental performance after controlling for economic development, both economic structure, measured as the relative shares of agricultural and service sector outputs, and government effectiveness have a positive relationship with environmental performance.

6.1 Concluding remarks and policy implications

Although the notion of economic development driving improvements in environmental performance has been investigated previously, the studies have found mixed evidence depending on the data and statistical methods used (Stern, 2004; Tsurumi & Managi, 2010). Earlier studies have found some emissions, such as CO_2, to either monotonically increase with income, and some, such as SO_2, to form an inverted U-shaped curve by having increasing emissions with income at lower income levels but decoupling at higher income levels (Tsurumi & Managi, 2010). In this study, the broader environmental quality was found to improve at any given level of economic development. This suggests that increases in emissions are offset by other improvements in environmental quality.

The identified key drivers of the relationship, however, show mixed evidence. The shares of agriculture and service sectors had a statistically significant and positive relationship with environmental performance, but despite earlier studies suggesting a negative relationship between the manufacturing sector and environmental performance, no such relationship was found in this study. A positive relationship was found between government effectiveness and environmental performance. However, the study failed to find support for trade openness having any impact on environment. Differences among countries at similar income levels are thus expected to be explained by variation in economic structure and government effectiveness. A comparison between CO_2 emissions reveal that some factors that are significantly related to the EPI are insignificant for CO_2, and vice versa. The most interesting difference in results is that the trade openness has a positive relationship with CO_2 emissions when controlling for HDI, but this does not hold when controlling for GDP. However, the models with CO_2 as the dependent variable do not pass all the robustness tests.

As noted by Grossman and Krueger (1991), among many other scholars, policy-makers should not rely on economic growth as the solution to environmental degradation. This study emphasizes the more complex role of economic development as a combination of income, human capital and public health. Studies often implicate the government as a major contributor to environmental performance, due to the public-good nature of environmental quality. This study supports the role of an effective government as a key factor for improved environmental performance, in particular for high-income countries. An effective government is likely to be able to implement stronger environmental policies, which have the potential to improve environmental quality and environmental health.

6.2 Limitations and future research

Perhaps the greatest limitation of the result is the lack of non-dynamic nature of the model. The environmental performance variable used in the study does not allow panel data regression due to a lack of comparability between observation years. Therefore, the relationship between environmental performance and economic development is estimated using a cross-sectional OLS model, which is econometrically limited. Economic growth is a long-term phenomenon and observing a single time point will exclude this dynamic behavior. Panel data would allow using econometric methods for determining Granger causalities and cointegrations.

A strength of the results is the inclusion of a wide selection of countries from all income levels and geographical locations. However, the data availability, especially at lower income levels, poses another limitation to the study. Developed countries have more advanced reporting systems and are therefore able to collect more detailed data on some of the issues studied in this thesis. Developing countries may lack the resources to collect such comprehensive data. There is a need to collect more data on the environmental regulations in low-income countries, and it must be comparable with the data from high-income countries to allow analysis of the relationship between environmental regulation and performance. In this study, as many countries as possible were included from lower income levels. However, some of the data on additional factors were excluded, as it would have introduced more bias toward high-income countries.

Future research could improve these results by investigating the indicators of environmental performance individually. In this study, environmental performance was measured with an index containing several measures of environmental quality. Therefore, a more detailed analysis of the indicators could reveal where economic development has the most significant impact, and where other factors play a bigger role. Furthermore, future studies could explore more factors likely to drive the relationship between economic development and environmental performance. The factors examined here were often connected to air pollution, but not to other environmental issues. By analyzing the factors driving different environmental issues, policymakers could take correct actions on environmental issues and address the threats to public health posed by environmental damages.

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Appendix A

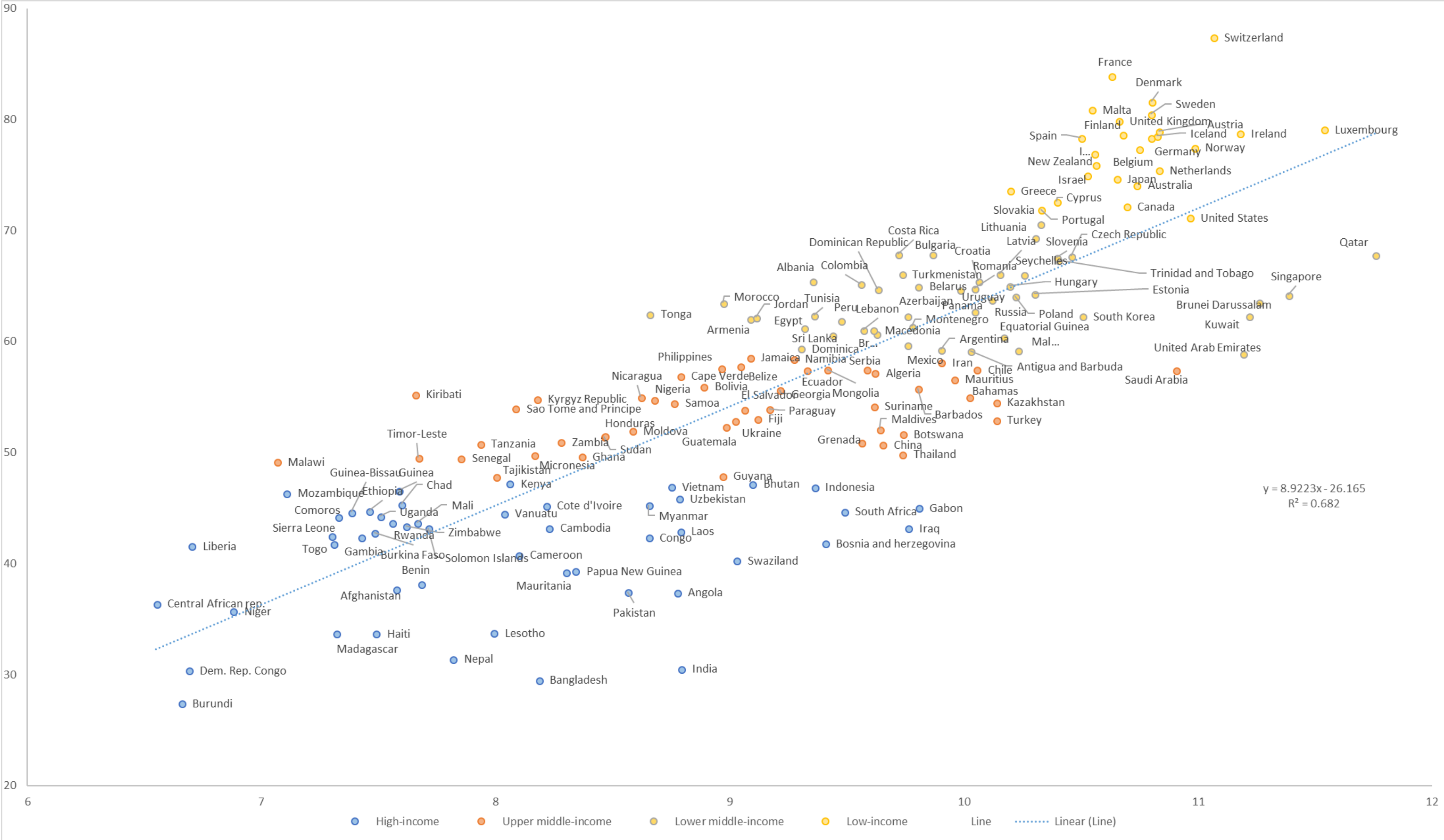

Figure A. The relationship between GDP (ppp) per capita and environmental performance. World Bank (2017), EPI (2018)

Appendix B

Table B. The indicators and weights of environmental performance index. EPI (2018)

Indicator &weight	**Title**	**Weight**	**Indicator**	**Measure**	**Weight**
Environmental Health **0.40**	Air Quality	0.65	Household Solid Fuels	DALY[1] rate	0.40
			$PM_{2.5}$ Exposure	µg/m^3	0.30
			$PM_{2.5}$ Exceedance	% population[2]	0.30
	Water & Sanitation	0.30	Drinking Water	DALY rate	0.50
			Sanitation	DALY rate	0.50
	Heavy Metals	0.05	Lead Exposure	DALY rate	1.00
Ecosystem Vitality **0.60**	Biodiversity & Habitat	0.25	Marine Protected Areas	% of EEZ[3]	0.20
			Biome Protection (National)	% of biomes	0.20
			Biome Protection (Global)	% of biomes	0.20
			Species Protection Index	Unitless[4]	0.20
			Representativeness Index	Unitless[4]	0.10
			Species Habitat Index	Unitless[4]	0.10
	Forests	0.10	Tree Cover Loss	%, 5-year	1.00
	Fisheries	0.10	Fish Stock Status	% of catch	0.50
			Regional Marine Trophic Index	Unitless[5]	0.50
	Climate & Energy	0.30	CO_2 Emissions – Total	kt CO_2eq/B$	0.50
			CO_2 Emissions – Power	g CO_2/kWh	0.20
			Methane Emissions	kt CO_2eq/B$	0.20
			N_2O Emissions	kt CO_2eq/B$	0.05
			Black Carbon Emissions	Kt CO_2eq/B$	0.05
	Air Pollution	0.10	SO_2 Emissions	Mt/$[6]	0.50
			NO_X Emissions	Mt/$[6]	0.50
	Water Resources	0.10	Wastewater Treatment	%	1.00
	Agriculture	0.05	Sustainable Nitrogen Management	Unitless[7]	1.00

1) age-standardized disability-adjusted life years lost due to risk
2) proportion of population exposed to $PM_{2.5}$ concentrations that exceed WHO thresholds
3) exclusive economic zone
4) the species protection index refers to the "average area of species' distributions in a country with protected areas, the representativeness index is the ecological representativeness of a protected area, and species habitat index is the relative proportion of habitat to baseline year of 2001
5) RMTI is "a measure of the mean trophic level of fish caught by a country, which represents the overall health of the ecosystem"
6) in constant 2011 international dollars
7) "the SNMI indicator uses nitrogen use efficiency (NUE) and crop yield to measure the environmental performance of agricultural production" (Zhang & Davidson, 2016; cited in EPI, 2018)

Appendix C

Table C. EPI scores and income groups. World Bank (2017), EPI (2018).

Country	Group	EPI score	Country	Group	EPI score
Switzerland	HI	87.42	Poland	HI	64.11
France	HI	83.95	Venezuela	UMI	63.89
Denmark	HI	81.60	Russia	UMI	63.79
Malta	HI	80.90	Brunei Darussalam	HI	63.57
Sweden	HI	80.51	Morocco	LMI	63.47
United Kingdom	HI	79.89	Cuba	UMI	63.42
Luxembourg	HI	79.12	Panama	UMI	62.71
Austria	HI	78.97	Tonga	LMI	62.49
Ireland	HI	78.77	Tunisia	LMI	62.35
Finland	HI	78.64	Azerbaijan	UMI	62.33
Iceland	HI	78.57	South Korea	HI	62.30
Spain	HI	78.39	Kuwait	HI	62.28
Germany	HI	78.37	Jordan	UMI	62.20
Norway	HI	77.49	Armenia	LMI	62.07
Belgium	HI	77.38	Peru	UMI	61.92
Italy	HI	76.96	Montenegro	UMI	61.33
New Zealand	HI	75.96	Egypt	LMI	61.21
Netherlands	HI	75.46	Lebanon	UMI	61.08
Israel	HI	75.01	Macedonia	UMI	61.06
Japan	HI	74.69	Brazil	UMI	60.70
Australia	HI	74.12	Sri Lanka	LMI	60.61
Greece	HI	73.60	Equatorial Guinea	UMI	60.40
Taiwan*	-	72.84	Mexico	UMI	59.69
Cyprus	HI	72.60	Dominica	UMI	59.38
Canada	HI	72.18	Argentina	UMI	59.38
Portugal	HI	71.91	Malaysia	UMI	59.22
United States	HI	71.19	Antigua and Barbuda	HI	59.18
Slovakia	HI	70.60	United Arab Emirates	HI	58.90
Lithuania	HI	69.33	Jamaica	UMI	58.58
Bulgaria	UMI	67.85	Namibia	UMI	58.46
Costa Rica	UMI	67.85	Iran	UMI	58.16
Qatar	HI	67.80	Belize	UMI	57.79
Czech Republic	HI	67.68	Philippines	LMI	57.65
Slovenia	HI	67.57	Mongolia	LMI	57.51
Trinidad and Tobago	HI	67.36	Chile	HI	57.49
Latvia	HI	66.12	Serbia	UMI	57.49
Turkmenistan	UMI	66.10	Saudi Arabia	HI	57.47
Seychelles	HI	66.02	Ecuador	UMI	57.42
Albania	UMI	65.46	Algeria	UMI	57.18
Croatia	HI	65.45	Cabo Verde	LMI	56.94
Colombia	UMI	65.22	Mauritius	UMI	56.63
Hungary	HI	65.01	St. Lucia*	-	56.18
Belarus	UMI	64.98	Bolivia	LMI	55.98
Romania	UMI	64.78	Barbados	HI	55.76
Dominican Republic	UMI	64.71	Georgia	UMI	55.69
Uruguay	HI	64.65	Kiribati	LMI	55.36
Estonia	HI	64.31	Bahrain	HI	55.15
Singapore	HI	64.23	Nicaragua	LMI	55.04

Table C continues.

Country	Group	EPI score	Country	Group	EPI score
Bahamas	HI	54.99	Gabon	UMI	45.05
Kyrgyz Republic	LMI	54.86	Ethiopia	LI	44.78
Nigeria	LMI	54.76	South Africa	UMI	44.73
Kazakhstan	UMI	54.56	Guinea-Bissau	LI	44.67
Samoa	UMI	54.50	Vanuatu	LMI	44.55
Suriname	UMI	54.20	Uganda	LI	44.28
Sao Tome and Principe	LMI	54.01	Comoros	LI	44.24
Paraguay	UMI	53.93	Mali	LI	43.71
El Salvador	LMI	53.91	Rwanda	LI	43.68
Fiji	UMI	53.09	Zimbabwe	LI	43.41
Turkey	UMI	52.96	Cambodia	LMI	43.23
Ukraine	LMI	52.87	Solomon Islands	LMI	43.22
Guatemala	LMI	52.33	Iraq	UMI	43.20
Maldives	UMI	52.14	Laos	LMI	42.94
Moldova	LMI	51.97	Burkina Faso	LI	42.83
Botswana	UMI	51.70	Sierra Leone	LI	42.54
Honduras	LMI	51.51	Gambia	LI	42.42
Sudan	LMI	51.49	Republic of Congo	LMI	42.39
Oman	HI	51.32	Bosnia and Herzegovina	UMI	41.84
Zambia	LMI	50.97	Togo	LI	41.78
Grenada	UMI	50.93	Liberia	LI	41.62
Tanzania	LI	50.83	Cameroon	LMI	40.81
China	UMI	50.74	Swaziland	LMI	40.32
Thailand	UMI	49.88	Djibouti	LMI	40.04
Micronesia	LMI	49.80	Papua New Guinea	LMI	39.35
Libya	UMI	49.79	Eritrea	LI	39.34
Ghana	LMI	49.66	Mauritania	LMI	39.24
Timor-Leste	LMI	49.54	Benin	LI	38.17
Senegal	LI	49.52	Afghanistan	LI	37.74
Malawi	LI	49.21	Pakistan	LMI	37.50
Guyana	UMI	47.93	Angola	UMI	37.44
Tajikistan	LMI	47.85	Central African Republic	LI	36.42
Kenya	LMI	47.25	Niger	LI	35.74
Bhutan	LMI	47.22	Lesotho	LMI	33.78
Vietnam	LMI	46.96	Haiti	LI	33.74
Indonesia	LMI	46.92	Madagascar	LI	33.73
Guinea	LI	46.62	Nepal	LI	31.44
Mozambique	LI	46.37	India	LMI	30.57
Uzbekistan	LMI	45.88	Democratic Rep. Congo	LI	30.41
Chad	LI	45.34	Bangladesh	LMI	29.56
Myanmar	LMI	45.32	Burundi	LI	27.43
Cote d'Ivoire	LMI	45.25			

*) income classification missing

Appendix D

Table D. Correlation matrix.

	EPI	CO_2	HDI	GDP	Agriculture	Manufacturing	Services	Gov. eff.	Corr. control	Trade	FDI	Pop. density	Urbanization
EPI	1												
CO_2	0.6972	1											
HDI	0.8625	0.8464	1										
GDP	0.8258	0.8743	0.9426	1									
Agriculture	-0.6321	-0.7656	-0.7967	-0.7925	1								
Manufacturing	0.1869	0.2077	0.2721	0.2578	-0.2207	1							
Services	0.6013	0.5605	0.6372	0.5662	-0.6292	-0.0273	1						
Gov. eff.	0.7882	0.6574	0.8329	0.8232	-0.6260	0.2438	0.5989	1					
Corr. control	0.7067	0.247	0.7145	0.6832	-0.5166	0.1104	0.5746	0.9178	1				
Trade	0.2407	0.2909	0.2702	0.2813	-0.2156	0.0801	0.2642	0.2810	0.2796	1			
FDI	0.4864	0.4795	0.5449	0.5628	-0.4338	0.3704	0.2294	0.5244	0.3251	-0.0516	1		
Pop. density	0.0829	0.0376	0.1045	0.0676	-0.1614	0.1023	0.2636	0.1758	0.1146	0.1158	0.0841	1	
Urbanization	0.6575	0.6410	0.7064	0.7298	-0.6111	0.1459	0.4234	0.5683	0.5122	0.1555	0.4924	-0.0155	1

Appendix E

For the model to be a CLM, it needs to fulfill the Gauss-Markov assumptions and additionally the assumption of a normally distributed error term (Wooldridge, 2012: 119). There are five Gauss-Markov assumptions. First, the model needs to be linear in parameters. This means, that the coefficients are the "unknown parameters (constants) of interest and [the error term] is an unobserved random error or disturbance term" (Wooldridge, 2012: 82). Second, the sample must be random, but representative of the full population (ibid: 84). Third, there should not be any perfect collinearity among independent variables. Although it is rare to have *perfectly* correlated independent variables in the model, this could result from adding a multiplicative form of another variable (ibid: 85). Fourth, the conditional mean of the error term should be zero. Error term should have an expected value of zero at any given x. A misspecification of the model or omitting an important variable can lead to failing this assumption (ibid: 86). Finally, the variance of the error should be the same at any given x. If the variance of the error term increases or decreases, the model suffers from heteroskedasticity (ibid: 93). This is often natural in economics, where higher income or wealth offers higher possibilities for different behaviors, such as consumption and saving (ibid: 52). When the first four assumptions are met, the ordinary least-squares (OLS) estimator is considered unbiased. When the fifth assumption is met, the OLS estimator is additionally considered efficient. Therefore, meeting all five assumptions makes the OLS estimator the best linear unbiased estimator (BLUE). (ibid: 101–102). The sixth assumption, which makes the model a CLM, is that the error is "independent of the explanatory variables […] and is normally distributed with zero mean and variance σ^2: [ε] ~ Normal (0, σ^2)" (ibid: 118).

According to Stern (2004), the EKC literature has generally suffered from heteroskedasticity and corrective actions for it have not been explicitly stated. For this reason, a special interest is given to the heteroskedasticity issue in this study. Homoskedasticity is expected for the estimators to be efficient. However, the presence of heteroskedasticity does not mean, that the estimators would be biased or inconsistent (ibid: 268). However, it means, that the OLS estimators are no longer efficient, and that the standard errors are biased. To determine, whether heteroskedasticity is present, the relationship between the error term and independent variables need to be tested. The null hypothesis is, that the square of the error term, given x, is a constant variance (ibid: 276):

$$H_0: E(u^2|x_1, x_2, \dots, x_k) = E(u^2) = \sigma^2 \qquad (5)$$

The term u^2 is assumed to be a linear function of x_j. If the slope coefficient(s) are equivalent to zero, and therefore, no relationship between x_j and error term exists, the null hypothesis can be rejected. By estimating the linear equation for u^2, F and LM statistics can be obtained. Under the null hypothesis, the LM is distributed as χ_k^2. This can be formally tested by using the Breusch-Pagan test for heteroskedasticity, which relies on the LM statistic. The p-value computed from the LM statistic will determine, whether the null hypothesis of homoskedasticity can be rejected or not. (ibid: 276–277). Another test is the White test for heteroskedasticity, which uses the same linear model of u^2 as the Breusch-Pagan but adds the squares and cross products of the independent terms. The coefficients for each of the x_j needs to be zero in order to confirm, that there is no relationship between u^2 and one or more of the independent variables. The p-value is obtained from the LM statistic, as in Breusch-Pagan test. (ibid: 279). There are ways to correct for heteroskedasticity. The first is to exclude possibilities of misspecifications, such as omitted variable bias. The second is to use heteroskedasticity-robust standard errors instead of the usual standard errors. The third way is to use weighted least squared (WLS) estimators instead of OLS. (Wooldridge, 2012: 279).

Addition to the heteroskedasticity issue, this study will test for the most common robustness issues with available formal tests. A common issue with econometric analysis is the misspecification of the model by including too few variables, leading to omitted variable bias. The regression specification error test (RESET) detects functional form misspecifications that could occur in the model by adding polynomials of the fitted values (Wooldridge, 2012: 306–307). The normality of residuals can be assessed by a graphical inspection of the distribution, but also by formal skewness/kurtosis test, where a p-value > 0.05 indicates, that the null-hypothesis of the normality of residual cannot be rejected. Multicollinearity is detected by calculating the variance inflation factor (VIF), which measures correlation among the independent variables (Wooldridge, 2012: 98). There is no definite value, that would automatically indicate an issue with multicollinearity. Rather, the aim is to keep the value low, most commonly under 10 (Wooldridge, 2012: 98).

The results for the robustness checks for the estimations of the models used in this study are summarized in Table E below.

Table E. Summarized robustness checks

Estimation	Skewness/Kurtosis	Breusch-Pagan/ Cook-Weisberg	Ramsey RESET	Variance inflation factor (mean)
(1)	0.2175	0.0033	0.0001	1.71
(2)	0.3129	0.0113	0.0006	2.42
(3)	0.2060	0.0029	0.0003	1.62
(4)	0.2508	0.0054	0.0000	1.93
(5)	0.4625	0.0587	0.0015	2.46
(6)	0.5820	0.1154	0.1132	1.69
(7)	0.5835	0.5095	0.0003	1.42
(8)	0.8673	0.4683	0.5076	1.28
(9)	0.3484	0.2392	0.5402	1.51
(10)	0.3606	0.3301	0.2417	1.47
(11)	0.0914	0.2305	0.1303	1.40
(12)	0.6914	0.9509	0.2934	1.25
(13)	0.1522	0.0119	0.5840	1.16
(14)	0.1718	0.0019	0.0251	2.80
(15)	0.0476	0.0000	0.1609	2.53
(16)	0.0899	0.0002	0.2633	2.27
(17)	0.2187	0.0204	0.0802	2.80
(18)	0.3677	0.1548	0.0728	2.98
(19)	0.1175	0.0012	0.3940	2.72
(20)	0.0788	0.0001	0.2643	2.82
(21)	0.0000	0.0000	0.9841	3.00
(22)	0.0000	0.0000	0.6011	2.84

Values in the table represent the p-values for skewness/kurtosis, Breusch-Pagan/Cook-Weisberg and Ramsey Reset.